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THE

MINERS' COMPANION

AND GUIDE:

A

Compendium of most Valuable Information

FOR

THE PROSPECTOR, MINER, GEOLOGIST,
MINERALOGIST AND ASSAYER;

TOGETHER WITH

A COMPREHENSIVE GLOSSARY OF TECHNICAL PHRASES
USED IN THE WORK.

48472

PROFUSELY ILLUSTRATED.

SAN FRANCISCO, CAL.
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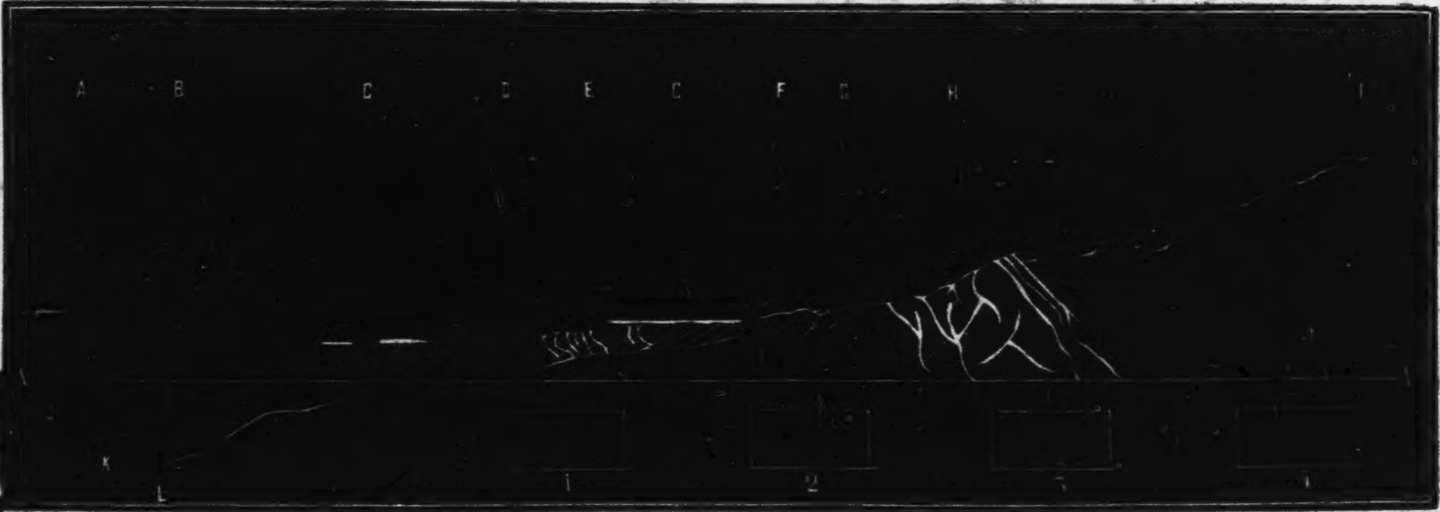
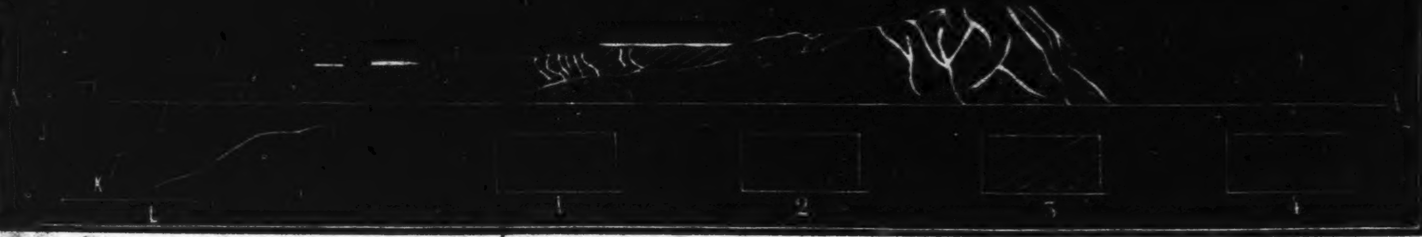
1861.

GEOLOGICAL SECTION OF THE SIERRA NEVADA.—[See pp. 159—171.]



1. Granite. 2. Amphibolite. 3. Cambrian strata. 4. Syenites and Greenstones.
A A. Level of the ocean.
A. Alluvial deposits, ancient and modern. B. Horizontal tertiary strata of Knight's Ferry. C. Basaltic Table Mountains. D. Mountains of serpentine cutting through the schists. E. Auriferous veins of quartzites or metamorphic sandstones. F. Saccharoid limestones, (blue and white marbles). G. Gneiss and micaceous schists. H. Auriferous veins of quartz and felspathic veins. I. Summit of the Sierra Nevada, with ancient volcanic cones. J. Tertiaries and Diluvium. K. Schists. L. Granites.

KNOX'S IMPROVED PATENT AMALGAMATOR.



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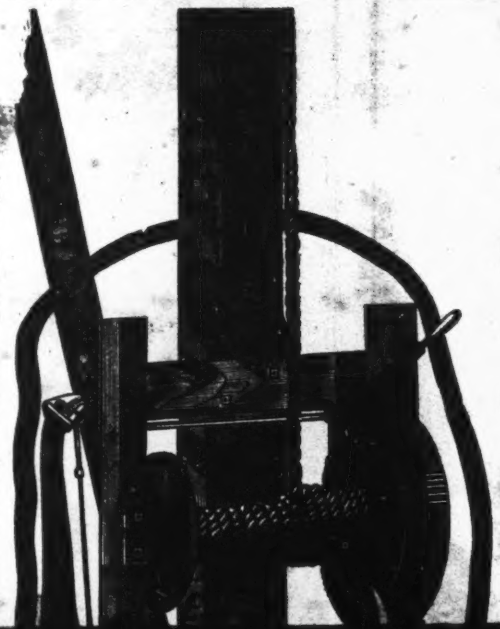

AULIC WATER WHEEL.—[See page 185.]

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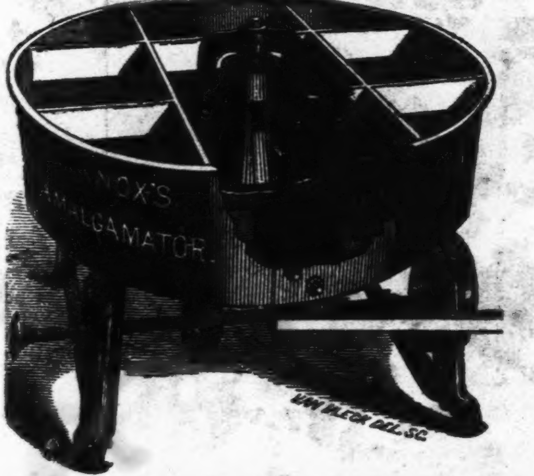
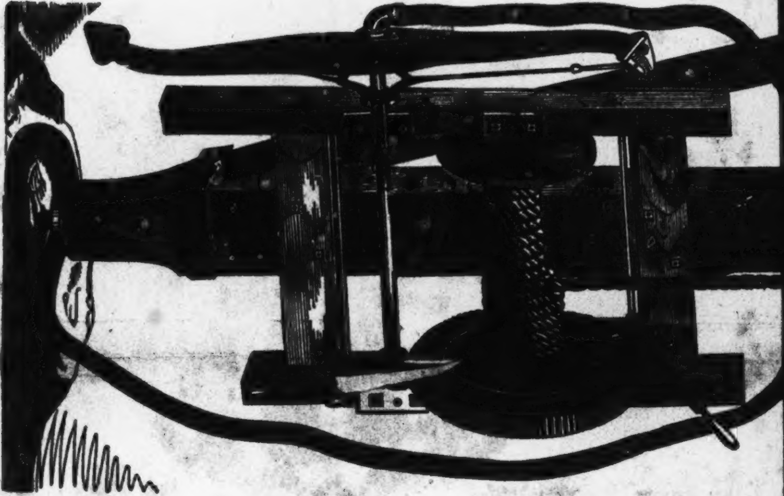
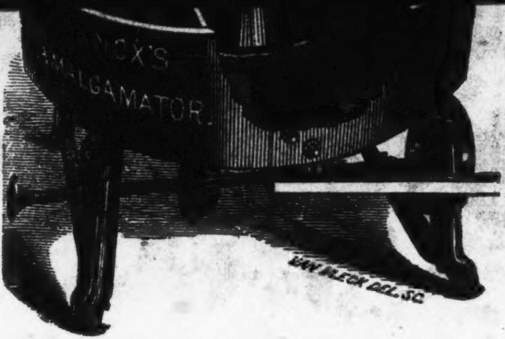


On page 193 we refer to Amalgamators usually em-

MATTESON'S HYDRAULIC WATER WHEEL.—[See p





On page 193 we refer to Amalgamators usually employed in the Pacific States. The above is at present the *only one* of its kind in existence, and has attained a greater celebrity than most others for its thorough working and application for the separation of both Gold and Silver ore.

[For INDEX, see p. 231.]

Entered according to Act of Congress, in the year 1861,
By J. SILVERSMITH.
In the Clerk's Office of the District Court of the United States for the Northern Dist. of California.

COMMERCIAL STEAM PRESSES,
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PREFACE.

California, since the grand exodus of the nations to her shores, commencing in 1849, has been regarded by the world, almost entirely in the light of a vast gold-field. The prodigous quantities of the precious metal flowing in one continuous stream ever since that time, from her mountains and *placeres*, into the lap of Europe and America, and Asia, have justly earned for her the proud title of the GOLDEN STATE. But her mineral resources are by no means restrictad to the noble metal—she boasts the ignoble as well. Her mines of rich cinnabar have become famous. Her silver, copper, iron and lead mines, to say nothing of her coal fields, will yet excite the envy of other countries.

Heretofore the attention of our miners has almost entirely been absorbed in the search for gold; but a partial revulsion is taking place, and they are beginning to learn that their time may, in certain localities, be more profitably employed—and it seems like a dispensation of Providence, that at a time when our surface diggings are yielding less profitably than of old, and many of them entirely exhausted of their riches, new and unexpected fields for mining enterprise develope themselves. Naturally enough, at such a time, the practical miner feels the necessity of having a portable mineralogical compendium, to which he can at all times refer when he is in doubt as to the nature of ores coming beneath his notice. Many a fortune has been within the reach of the prospector, but eluded his grasp, simply because a handy work of reference was not in his possession. Most discoveries thus far have, in the main, been made by the merest accident, or a vague but fortunate suspicion. How invaluable then, to those engaged in "prospecting," or actual mining, would be a convenient book in which they can find, in brief yet comprehensive shape, not only information touching the geological structure of the earth, the methods of veins, the geognostic situation, external character or appearance of the various ores, and the simplest methods of testing them; but a system of mineralogy, and the best manner of working them when found! Such a work is the "MINER'S COMPANION AND GUIDE—" which for the most part is a compilation of treatises and books whose authors rank high in the fields of geological and mineralogical research. To procure the valuable works from which we have extracted, would involve a large expenditure compared with the trifling cost of the one we herewith present to our mining community.

At considerable expense we have had wood-cuts prepared, so as to faithfully represent the subjects treated of. These illustrations and diagrams will render the most difficult portions of our volume perfectly intelligible to the general reader.

The "MINER'S COMPANION AND GUIDE" is mainly indebted to the works of Whitney, Werner, Ure, Phillips and Orton, and we are sure that in saying this, the miners on this coast will fully appreciate its great value. No miner or prospector, anticipating the smiles of a herertofore perverse fortune, should be without it.

MINERS' COMPANION AND GUIDE.

On the Nature of the Deposites of the Metals and their Ores, and the General Principles on which Mining is Conducted.

Before entering upon a description of the mode of occurrence and geological position of the various metals and their ores, taken singly, it will be well to establish the meaning of some of the more important terms used in treating of subjects of this kind, and to lay down some general principles which the results of mining-experience have shown to be applicable to mineral and metallic deposits. The importance of this preliminary step will be acknowledged when it is considered that these principles are derived from the combination and classification of facts observed in mining operations all over the world and that they form the basis on which future enterprises of this kind should be organized. The results which have been obtained in this branch of applied science are drawn from a great variety of sources; and when we reflect on the expense and well-known uncertainty attendant on mining, it will be evident that, amid the multitude of isolated facts, to which every day is adding, some general principles should be recognized which may be relied on as a thread to guide one through the labyrinth of uncertainty.

Great as is the variety of forms under which the metalliferous deposits of different regions appear, and difficult as it may seem at first sight, to discern any fixed laws in their development, yet, a general consideration of their structure will justify the following classification:

- 1. SUPERFICIAL.
- II. STRATIFIED.
  - *a*. Constituting the mass of a bed, or stratified deposit.
  - *b*. Disseminated through sedimentary beds.
  - *c*. Originally deposited from aqueous solution, but since metamorphosed.
- III. UNSTRATIFIED.
  - *a*. masses of eruptive origin.
  - *b*. disseminated in eruptive rocks.
  - *c*. Stockwerk deposits.
  - *d*. Contact deposits.
  - *e*. Fahlbands.
  - *f*. Segregated veins.
  - *g*. Gash veins.
  - *h*. True or fissure veins.

A. Regular. B. Irregular.

I. SUPERFICIAL DEPOSITS.—These comprise all deposits of the metals and their ores, which lie loose upon the surface, or intermingled with the superficial formations, the drift, and the alluvial. They are made up of particles and rounded fragments which have originally formed a part of some bed or vein, and from which they have been detached by various causes similar to those which have produced the great masses of clay, sand and gravel, which almost everywhere cover the rocks in place. Such metalliferous deposits are usually called washings or stream-works. Most of the gold and all of the platina of commerce is obtained in this way, as also some of the tin. Their discovery and exploitation is hardly to be classed under the head of mining operations, although they furnish large amounts of the most valuable metals. Lying so near the surface they can be reached by excavations of the most simple character. The dissemination of the metallic substances through the loose materials in which they are imbedded is the result of mechanical causes, especially of currents of water, which have torn them from their original bed and scattered them over the surface.

II. STRATIFIED MINERAL DEPOSITS.—This class of deposits comprehends those masses of ore which are included within rocks of sedimentary origin, and which are in every way identical in their epoch and mode of formation with the strata between which they are accumulated. This is not, however, the mode of occurrence of the more valuable metals. Of all the metalliferous ores, those of iron and manganese only occur in stratified deposits on an extensive scale. The beds of argillaceous ironstone, intercalated among the shales of the coal series, furnish the most striking illustration of this mode of occurrence, as will be fully set forth elsewhere.

There are also strata of slaty and other rocks which are impregnated with ore, or contain it disseminated through them in small particles, so thoroughly intermingled with the rocks as to be hardly distinguishable from it. When such deposits occur on an extensive scale, and when the ore forms a persistent portion of the stratum, they become an important source of mineral wealth ; although the percentage of ore is usually very small, yet from their greatextent, they may be capable of being worked with profit. Such are the cupriferous schists and sandstones of the Mansfield district in Prussia, and the similar deposits of the government of Perm in Russia.

There is a class of metalliferous deposits which belong to rocks originally stratified, and of aqueous origin, but which have, since their deposition, been metamorphosed so as to have assumed in a great degree the appearance of igneous masses, and which themselves can with difficulty be recognized as possessing distinctly the character of either the stratified or unstratified groups. These are developed in the metamorphic strata of the palæozoic system, but especially in the azoic rocks, as in Sweden and in Northern New York, where the immense deposits of iron ore furnish examples of the class in question. They invariably coincide in their line of greatest linear development with the line of strike of the associated rocks, and are exceedingly irregular in their dimensions, expanding to a great width and then contracting within very narrow limits. They usually also agree in dip with the planes of the rock enclosing them. Such masses of ore seem to have resulted originally from aqueous deposition, although the materials may in some instances have been derived from the abrasion and destruction of purely igneous masses. It is frequently supposed that these lenticular, or flattened cylinder-shaped deposits have been forced up in a plastic state from beneath, having been driven in between the strata like a wedge, separating them along the line of least resistance. This theory, however, seems hardly tenable, when we consider the great extent of such masses, and the absence of rubbed and polished surfaces along the line of contact of the ore and of the adjacent rock. Moreover such masses are sometimes found thinning out beneath, as if they had occupied a previously existing-depression in the strata, before they had been elevated from their original horizontal position. When such an upheaval of metallic matter has taken place from beneath, we find the result of mechanical displacement and chemical action in the surrounding beds to be most strongly marked. The azoic period having been one of long-continued and violent mechanical action, there is no reason to doubt that many of the masses of which it is made up may have been derived from the ruins of previously formed rocks of the same age, both sedimentary and igneous. Such abraded material might readily have been swept into the depressions of the surface by strong currents, such as must have existed in those times, and would naturally have a very irregular thickness.

III. UNSTRATIFIED DEPOSITS—This class comprehends most of the deposits of the ores of the metals, excepting some of those of iron and manganese, as noticed above. Their character is exceedingly varied, and the phenomena which they exhibit,frequently of the most complex kind.

In the first place they may be divided into two great groups, *Irregular and Regular Deposits.*

Irregular Deposits.—These include first, igneous eruptive masses, forming rock aggregations in every respect similar in form and mode of occurrence to the nonmetalliferous rocks with which they are associated. This class of deposits consists chiefly of the immense masses of specular and magnetic oxides of iron, so strikingly developed in the azoic system, where they exist in connection with igneous eruptive rocks, and apparently under the same conditions and with the same mode of occurrence. In Europe, the Elba iron ores may be taken as a type of this class of ore deposits ; in this country, the Iron Mountain of Missouri, and the even more extensive iron ridges of Lake Superior, furnish striking examples of a metalliferous ore existing in such quantity and under such circumstances as to identify it geologically with the adjacent rock formations and to cause it to be classed with them, as having originated under the same circumstances. Such bodies of ore usually form ridges parallel with the lines of elevation of the rocky strata in which they occur, or they may take the form of dome-shaped masses which have lifted up the strata on every side, usually filling the fractured envelop with metallic emanations, and showing an intense metamorphic action in the formation of numerous mineral substances not elsewhere found occuring in the formation. As might reasonably be expected, such ore-masses are often developed on the largest scale in the azoic system, having been formed at a period in the geological history of the earth when its crust was thinnest and most easily fractured. If there have been eruptions of metalliferous masses during the later geological periods, they have taken place usually in a region of volcanic fires, or on deeply seated fissures which have remained opened until a late epoch.

As far as the practical application of mining science to this class of deposits is concerned, it is the most simple, for they are developed on so grand a scale that there is no question of exhausting them, and when worked, it is generally by excavations of the nature of the quarry rather than of the mine. In that part of Whitney's "Metallic Wealth," treating of the geological occurrence of ores of iron, numerous examples are given of this form of metalliferous deposit, which is almost exclusively confined to that class of metalliferous products.

Closely allied to the last-mentioned class is that of the metals and ores disseminated in the eruptive rocks, when the quantity of the metalliferous substance has not been sufficient to form a special deposit, or when the nature of the circumstances under which it was formed has not permitted its concentration. This is the mode of accurrence of platina and its associated metals, which are disseminated through eruptive trappean or serpentine rocks in fine particles, and rarely masses of a few pounds in weight; but which have never, thus far, been found in regular veins or in any concentrated form of deposit. Serpentine is frequently accompanied by chromic iron, which is disseminated through it in the same way, but much more abundantly. The trappean rocks contain frequently so large a proportion of the magnetic oxide of iron, scattered through the mass, that it may be considered one of the constituent minerals of the rock. Thus, in the mine of Taberg, in Sweden, the trap is so filled with bunches and strings of magnetic iron ore that it can be worked to advantage.

But in general, this class of deposits are of little value, unless nature has performed the operation of separating the metallic contents on a grand scale, by a gradual disintegration and removal of the rocky substance, and the consequent concentration of the much heavier metal or ore. This is the origin of all the platina-washings, which metal was derived from the abrasion of a rock containing it in so small a proportion that it could never have been separated by artificial means, with profit.

The tin mines of Europe, are, many of them, worked in deposits analogous in their mode of occurrence to those now under consideration. For instance, at Geyer in Saxony, the oxide of tin is found in small thread-like veins, and disseminated in fine particles through an eruptive dome-shaped mass of granite. It is from an original source resembling this, that the tin of the washings or stream-works of England and the East Indies has been in part derived. Oxide of tin is sometimes disseminated in invisible particles through the granite rocks, and would probably be frequently found if carefully searched for. Prof. Whitney found 0-13 per cent. of this substance in a feldspar from the Riesengebirge, in Silesia, in which not a particle of it was visible to the eye.

Closely allied and passing into the last-mentioned mode of occurrence is that called by the Germans a "Stockwerk," a term which has been adopted into French and English, although not always correctly applied. The Stockwerk consists of a series of small veins, interlacing with each other and ramifying through a certain portion of the rock. The ore is not usually entirely confined to the veins or branches, but exists in the adjacent rock in considerable quantity.

The annexed section (Fig. 1) represents such a network of veins, and the manner in which they may be imagined to traverse the rock.

Such reticulations of mineral matter are frequently called in England, "Floors," and in Germany, "Truemerstœcke," or "Stockwerke," in allusion to the fact that they are worked in different stages or stories, one above the other, owing to their great extent. Such deposits are usually proportionally poor in metallic contents, in an average of the whole quantity of rock which has to be worked.

Fig. 1.

The celebrated Carclase tin mine, near St. Austell, is a striking example of the stockwerk form of deposit. It was worked until recently, in a decomposed feldspathic granite, as an open quarry. The ore occurs in a network of small veins interlacing with each other, the whole of which, together with the rock included between them, had to be removed, and the ore afterwards separated by hand-picking, stamping, and washing.

There are other Stockwerk mines in Cornwall, most of which have now been worked out and abandoned. The Altenberg stockwerk, in Saxony, furnishes another good example of this mode of ocurrence. The rock is a grayish silicious, feldspathic porphyry. The stanniferous mass is about 1400 feet long, and 900 feet wide,and like that described above consists of a number of small veins, which cross each other in every direction. Those which run nearly east and west are usually the widest and richest in ore. The enclosing rock is also rich enough to be stamped and washed for a distance of several feet from the network of veins.

In the phenomena of contact deposits, segregated veins, and true veins, there is a gradual passage from one class of forms to the other, so that it is not always easy to say to which of these divisions a deposit of ore may belong. In the class of contact deposits, the ore is found concentrated between two formations of dissimilar geological and mineralogical character. Where the strata have been uplifted and metamorphosed by a central eruptive mass, not unfrequently a band of metalliferous ore, of irregular thickness will be found extending along the line of contact of the eruptive with the metamorphosed rock. Or, if not always exactly upon the dividing line between the two formations, it may be found perhaps at an inconsiderable distance, and preserving a general parallelism with it. The annexed figure (2), illustrates, by an ideal section, this mode of occurrence.

Fig. 2.

a. Contact deposit of ore bet. 2 formations.

In the same manner, beds of ore may be found between two successive overflows of an igneous rock, or metallic substances may occur disseminated through that portion of two beds of rock which is adjacent to the plane of separation between them ; in such a case the mineral masses on each side of the ore deposit may have the same geological position, but will usually be found to differ in mineralogical charater. Farther on, interesting examples of this mode of occurrence in the Lake Superior region, will be given. The iron ores of the Harz have a similar position in relation to the eruptive rocks of that district, since they follow the contact-planes of these igneous masses with the uplifted slates. The deposits of ore pass gradually into the trappean rock, showing that there has been a concentration of metallic matter at the junction of two dissimilar formations. The same phenomena exhibit themselves in the Vosges, near Framont, where masses of specular iron surround a central nucleus of quartzose porphyry, which has tilted up the stratified rocks, while the ore has insinuated itself into all the fractures and cavities thus produced, lining them with beautiful crystals and penetrating even into the solid rock itself. At this locality, and others resembling it, the action may be considered to have been principally of an igneous character, the upheaval of the strata opening a passage or chimney for the passage of metallic vapours which have become condensed in the fissures thus formed. In other cases the phenomena are more satisfactorily explained, by supposing a segregation of the mineral substance along the line of junction of two rocks of dissimilar character, under the influence of electro-chemical agencies. The copper ores of Monte Catini, in Tuscany, belong, according to Burat, to the class of contact deposits, being developed along the line of outcrop of the gabbro, a rock resulting from the metamorphic action of serpentine upon the strata of the cretaceous formation.

Deposits of the character thus indicated are exceedingly irregular in their outline, and are often so combined with each other as to present the features of two or three forms at once, but in general, in their essential characteristics, they are allied to the rocks in which they occur, in structure and composition. They are often developed at certain points on so large a scale as to be of great importance, but they have not that persistence in depth which is the characteristic of true veins. The ores which they furnish are less crystalline in their texture, and are often quite compact. The gangues are also less distinguishable from the adjoining rocks, and frequently there is no proper veinstone at all. In every mining district one or the other of these modes of occurrence usually predominates and gives a character to the workings ; if the deposits are of the irregular class, they are usually wrought with less skill and capital, although frequently on a very extensive scale ; if, on the other hand, they are regular in their character, they require an enlightened system of working, and may be relied on as permanent sources of metallic wealth. Of this description are the mines of Cornwall, Saxony and the Harz, which have been for hundreds of years the classic regions of mining, and in which the theory and practice of this branch of applied geology have been carried to the highest perfection.

Intermediate between the regular and irregular deposits of the metalliferous ores are those forms of occurrence designated by the German word, "Fahlband." These are more strikingly exhibited in Norway than elsewhere, although the same character has been recognized in other regions on a less extensive scale; and being in some respects peculiar, this mode of occurrence should not be overlooked in a review of the forms of metalliferous deposits.

The Fahlbands (German Fahlband; plural, Fahlbænder), as developed in the district of the Kongsberg silver mines, consist of parellel belts of rock of very considerable length and breadth, which are impregnated with the sulphurets of iron, copper, and zinc, together with a little lead and silver, disseminated through the rocks in such fine particles as to be hardly visible, and only to be recognized by their tendency to decompose, and thus to give the rock in which they are contained a peculiar rotten and disintegrated appearance at the surface: hence the name Fahlband, or rotten belt, the word *fahl* being a curruption of *faul*, the miner's term for a rotten or decomposed rock.

In general these ore-bearing belts are irregular in their dimensions, although constantly observing a certain degree of parallelism with each other. They may be traced in the Kongsberg silver-mining district for several miles, and the greatest depth of any one is about a thousand feet. The quantity of ore contained in them is usually too small to be worth working: but occasionally it is sufficiently concentrated to become the object of mining enterprise. There are seven of these Fahlbands in the vicinity of Kongsberg, and they are parallel in strike and inclination with the gneissoid and schistose strata in which they occur, and have the same local character in relation to disturbances of stratification, schistose structure, and other external forms.

The fahlbands, however, are themselves traversed by fissure-veins bearing argentiferous ores, and the results of extensive mining have shown that these veins are only productive when they intersect the fahlbands, demonstrating that the impregnation of the lode with mineral matter was entirely dependent on the nature of the adjacent rock, and furnishing sufficient evidence that the metalliferous particles in the veins were originally derived from the fahlbands, and probably concentrated there by electro-chemical action.

This mode of occurrence will be recognized as peculiar in its character, being a combination of two distinct forms of metalliferous deposits; but the fahlbands themselves could hardly be considered of much importance, were it not for their enriching action on the lodes which traverse them.

The same fact is observed with regard to the enriching of fissure-veins, when they traverse different beds of rock, even in cases where no perceptible metalliferous particles can be observed in any of them, and when the fahlband structure may be supposed to be wholly absent. In such cases it is not unreasonable to suppose that a chemical examination of these beds, in which a lode shows itself to be better filled with ore than elsewhere, might reveal the existence of metalliferous particles, the presence of which had been previously unsuspected, because they were too finely disseminated through the rock, or were not of a nature to be easily decomposed, and so failed to give a marked external to the stratum in which they occurred. The fahlbands may be considered as approaching nearest to the class of segregated veins, which comes next in the classification of metalliferous deposits given above, and to these, in connection with the other modes of occurrence to which the term Vein is applied, we now turn our attention.

Regular Deposits.—Segregated veins, Gash-veins, Fissure veins.—The line of demarcation between the three forms of veins indicated above, cannot always be easily drawn, although in most cases the difference is very apparent, and in all is of great importance in judging of the value of a metalliferous deposit. But in some instances, there is so gradual a passage from one form to the other, that surface examinations are not sufficient to enable one to decide the question of the actual existence of a fissure or true vein, and it is only by the indication obtained at some depth below the surface, that the vein can be placed in its proper class.

By a vein, as a geological and mining term, in general is understood *an aggregation of mineral matter of indifinite length and breadth, and comparatively small thickness, differing in character from, and posterior in formation to, the rocks which enclose it.*

Werner, the great Saxon geologist, defined veins as "mineral repositories of a flat or tabular shape, which traverse the strata without regard to stratification, having the appearance of rents or fissures formed in the rocks, and afterwards filled up with mineral matter differing more or less from the rocks themselves." This definition would exclude many veins which do not traverse, but run parallel with the strata, and others which occur in unstratified rocks. The definition given above, of course, includes veins of mineral matter not metalliferous, which are of frequent occurrence; but of course, no importance in the present connection.

Weissenbach, in a paper published in Cotta's "Contributions to the Knowledge of Mineral Veins," which is especially devoted to the subject of the metalliferous lodes of Saxony, has given a general classification of all the modes of occurrence which can be brought under the head of veins. He divides them as follows:

1. *Veins of Sedimentary Origin.*—Where a fissure has been filled from above by deposition of mineral matter, in a manner similar to that in which the sedimentary rocks themselves have been formed. The origin of these is exceedingly simple, since it is evident that in

the process of deposition of any of the stratified masses, as of sandstone or limestone for instance, if this operation were going on in a region where open fissures existed in the subjacent rock, they would be filled by the sedimentary matter, which would assume a stratified appearance in the fissure exactly as above it. The matter thus deposited would not properly be a metalliferous ore, since this class of products have a chemical not a mechanical origin. This is perfectly evident, and it cannot fail to strike one with surprise that a theory so inconsistent with facts should have been adopted by Werner to account for the formation of metalliferous veins. The whole class of veins of sedimentary origin is of little importance.

2. *Veins of attrition.*—Fissures filled with matter introduced by purely mechanical means, such as by fragments of the wall-rock falling from above, or produced by friction of their sides against each other. These phenomena are exhibited in many ore bearing veins, in the formation of which a two-fold action was concerned.

3. *Veins of Infiltration, or Stalactitic Veins.*—These result from the filling of fissures by incrustation of the sides with calcareous matter deposited from aqueous solution, in the manner of the stalactites so common in caverns.

4. *Plutonic Veins.*—Fissures filled with mineral matter identical with that of rock formations, or mountain masses, and supposed to have been introduced by injection, or pressure from beneath upwards, while in a plastic state. Such are the common granite veins in granite or slate.

5. *Segregated Veins.*

6. *Metalliferous Veins, proper.*

These two latter classes are included in the class of regular, unstratified mineral deposits,as previously shown in the table of mineral formations ; the latter division including both gash and fissure veins ; and they are the only ones which are of importance in the consideration of the metalliferous veins.

Segregated Veins.—Under this class of metalliferous deposits are included those vein-like masses which have a crystalline structure, or, at least, a gangue differing from the adjacent mass, but which do not seem to occupy a previously existing fissure in the rock, being so enveloped and limited on all sides within it, as to show that the metalliferous and mineral substances of which they are made up could not have been introduced into their present position in any other way than by a gradual elimination of their component particles from the surrounding formation. Their process seems to have been of a chemical nature, and one by which materials of similar character were collected together from all directions, or segregated, as it is termed. Of the conditions under which the adjacent rocks must have been when such an elimination of their metallic contents took place, we know little with certainty. We see, however, examples of segregation in masses of lava, as they cool from a state of igneous fluidity, when crystals of the different mineral species found in such rocks are found to have crystallized out into distinct individuals, from what was before an apparently homogeneous paste. The same is true of granite and the trappean rocks. In the former, the single crystals sometimes attain the length of several feet. If circumstances cause the segregating crystals to imitate an elongated mass, we have at once the rudimentary form of a veinlike mass, which may continue to develop itself and acquire considerable dimensions. A tendency to this separation of pure quartzose material will be noticed in almost all of the so-called metamorphic rocks, which frequently show bands of pure quartz, parallel with each other, and lying in the plane of stratification of the enclosing rock; and it should be noticed that quartz is almost universally the veinstone of ores occurring in this form of deposit.

These segregated veins differ from true veins in some important respects. In the first place they usually lie parallel with the cleavage planes of the formation in which they occur, which is the gneissic and schistose portion of the metamorphic palæozoic rocks. The annexed wood-cut (Fig. 3), represents an ideal section of the form of deposit here under consideration. The ore-bearing mass may or may not appear at the surface, but its extent downwards in one plane is not to be relied upon as in the case of a fissure vein, since the accumulation is liable, at any point, to be found thinning out in depth, and transferred to another plane as represented in the figure.

Fig. 3.

a. Segregated mass of ore cropping out at the surface.
b. Parallel layer not extending upwards so far.

A striking illustration of this form of deposit may be

Fig. 4.

Section of the Rammelsberg.

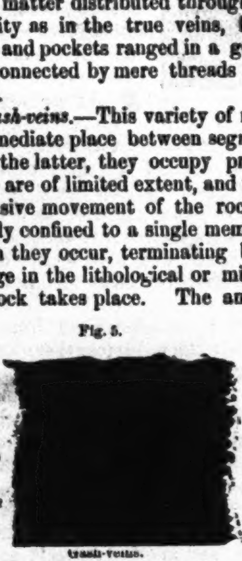
seen in the Rammelsberg, one of the most celebrated localities of the Harz, a section of which is given in the annexed cut (Fig. 4). The principal mass of ore (*a*, *c*), lies in the direction of the argillaceous slates of which the mountain is made up. At the depth of about four hundred feet, it sends off a branch (*b*), which dips at a considerably less angle than the slates themselves. The greatest thickness of the mass of ore is over one hundred and fifty feet ; and its length is about nineteen hundred ; but the dimensions decrease in depth, and at eight hundred feet its thickness is about twenty, and its length seven hundred and fifty feet ; so that there can be little doubt that the mass will terminate entirely at a certain not very great depth. The ores of this singular mass are chiefly sulphurets of iron, zinc, lead and copper, intimately blended together, and almost entirely destitute of gangue.

The auriferous quartz-veins of most gold regions belong to this class of deposits. They consist of belts of quartzose matter with sulphuret of iron, which near the surface is decomposed into a hydrated oxide, and contain gold disseminated through these substances, and sometimes in the adjoining rock, in fine particles, or, occasionally, large lumps. These belts run with the strata and dip with them, and in other respects exhibit the phenomena of segregated rather than of fissure-veins.

Practically, the most important feature of this class of deposits is that they cannot be depended on in depth as true veins; as they seem almost always to be richest near the surface, and frequently terminate altogether at no very considerable depth. Nor is the ore or metallic matter distributed through them with as much regularity as in the true veins, forming often a series of nests and pockets ranged in a general linear direction, and connected by mere threads of ore or barren veinstone.

Gash-veins.—This variety of mineral deposit holds an intermediate place between segregated and true veins. Like the latter, they occupy pre-existing fissures; but these are of limited extent, and not connected with any extensive movement of the rocky masses. They are usually confined to a single member of the formation in which they occur, terminating below, when a marked change in the lithological or mineralogical character of the rock takes place. The annexed cut (Fig. 5) represents, in an ideal section, the mode of occurrence to which the name of gash-veins is applied. The stratum *b*, included between *a* and *c*, cuts off the veins in *a* entirely, the fissures not having extended through that bed at all. Should circumstances favor, and the bed *c* resemble *a*, similar fissures may be

Fig. 5.



Gash-veins.

found again below *b*, as presented in the figure, but it can by no means be asserted that they are the continuations of the identical fissures which were found in *a*; on the contrary, they are a new set originating in and comprised in the bed *c*, as those above were in *a*. Lateral branches will usually be found in connection with the main fissures, which may or may not be nearly vertical, according to circumstances; but, whatever their position, the two sets of cracks will be nearly at right-angles with each other, and will possess the same character in regard to their mineral contents, although one set will generally predominate over the other greatly in extent.

The origin of this class of fissures must, in all probability be referred to the contraction of the rock caused by shrinkage, either while gradually undergoing consolidation, or from the effect of long exposure to a somewhat elevated temperature, after a cessation of which, certain strata might on cooling, under peculiar circumstances of texture and thickness, be more liable to be fissured than others.

The filling of fissures thus originating with mineral substances may have taken place in various ways. Most of them in process of deposition, if they occurred in strata still accumulating. In a rock impregnated with metalliferous combinations,segregation would more readily take place from the walls of such cavities, and their contents would then have the characters of those of segregated veins. From true fissure veins they differ especially in not showing as distinctly marked selvages, and in having a less crystalline and comby structure of the veinstone. They are especially to be found in the unmetamorphosed sedimentary rocks, where these have undergone so little change as not to have assumed a thoroughly crystalline texture, and have retained the original lines of stratification, which, in the fully altered rocks, are almost obliterated.

The difference between segregated and gash-veins may be sometimes hardly perceptible, but their origin is sufficiently distinct to justify their separation from each other ; and there are mining regions where the peculiarities of one form or the other may be seen with great distinctness. The latter are still less reliable than the former, and are usually soon worked out in depth ; but frequently their number makes up for a want of continuous extent in any one of them, so that a region where they abound may furnish, for a time, a large amount of ore.

True Veins.—A true vein may be defined as a fissure in the solid crust of the earth, of indefinite length or depth, which has been filled more or less perfectly with mineral substances ; or, in other words, an aggregation of mineral matter, accompanied by metalliferous ores, within a crevice or fissure which had its origin in some deep-seated cause, and may be presumed to extend for an indefinite distance downwards.

These veins are almost universally admitted by geologists to have originated in faults or dislocations caused by great dynamical agencies connected with extensive movements of the earth's crust, and for this reason they are believed to extend indefinitely downwards ; an assumption which is supported by facts, since no well-developed and defined vein has ever been found entirely terminating in depth. Gash-veins, on the other hand, as before remarked, occupying fissures which have resulted from shrinkage of the rock, cannot be expected to extend into strata of different character from that of the bed in which they originated.

Among all the forms in which the metalliferous ore occur, that of true veins is of much the greatest interest, since they are the principal repositories of the ores of the useful metals, and their exploitation is a matter of lasting importance, involving the employment of both skill and capital ; hence their principal features require to be described somewhat in detail.

The linear extent of true veins is very various in different instances. Some of the longest known have been traced many miles ; but usually, even if they extend for so considerable a distance they are not found to be impregnated with ore through the whole of their course. The longer the vein, as a general rule, the more likely it is to be, in some part of its course, rich in ores ; thus some of the great veins of Mexico, which have produced such enormous quantities of ore, have been followed for more than six miles, and have been opened and worked in a great number of places. The width of a vein is not necessarily in relation to its length ; some, which are well-defined and traceable to a great distance longitudinally, are quite narrow. From the nature of their origin their direction and dimensions must be somewhat irregular, since the two portions of the rock on each side of the original crack having been moved in relation to each other, the uneven sides of the fissure will have given rise to cavities of unequal width. That such motion has taken place, is abundantly proved, in numerous instances by the actual displacement of strata or mineral masses once evidently continuous and now removed to a greater or less distance from each other both in a vertical and a horizontal direction. Such cracks frequently exist in the stratified rocks, and have not been filled up with mineral and metallic substances; in such cases when there has been a perceptible vertical movement of the two sides in regard to each other, the break of continuity is called a "fault."

Fissures thus formed may have been the receptacles of mineral matter unconnected with any metalliferous ores, as in the case of dykes of trap or veins of granite, which are usually considered to have assumed their present condition while in a plastic state. The filling of cracks in such cases was a process of short duration compared with the time required for the formation of veins containing metallic matter. In other instances there may be regular veinstone accumulated between the walls of a fissure, and yet ore be entirely wanting; but it is rare that this is the case, since in almost every vein in which mineral matter has slowly gathered, there have been metallic substances present in some part of its course, during some part of the time of its formation.

In regard to the occurrence of true metalliferous veins there is no fact more striking than that they are rarely found singly, but rather in groups, often in a complicated network crowded into a comparatively narrow space. The great mining regions occupy but a small part of the earth's surface; while very extensive tracts are almost wholly destitute of metalliferous indications. Let any one take a map of Europe and color upon it the best known mining districts, which furnish the larger portion of the metals to commerce, and he will be astonished at the small space which they cover. The groups of veins of the Cornish and Saxon mining districts are so complicated in their number and variety of relations to each other, that centuries of working upon them have not yet fully developed even the more important facts with regard to them:

The various minerals which make up the body of the lode are frequently arranged in a succession of plates parallel to its walls. Usually these plates, or combs, as they are called, are made up of aggregations of crystalline matter, the separate crystals of which have their axes at right-angles to the wall of the lode, and are developed on the side turned towards its centre. The annexed figure (Fig. 6) represents part of a lode at Wheal Julia, near Binner Downs, in Cornwall.* In this, which furnishes a good example of a comby structure, we see a central predominating mass of crystalline quartz (*e*) on each side of which are seams of copper ore (*f f*). This constitutes the main body of the lode. Between this central comb and the walls are two smaller combs of the same material, on each side, separated, in one instance, as seen at *c*, by a partition of earthy matter. Each comb consists of two corresponding portions, whose crystalline faces meet and interlock towards its centre.

Fig. 6

a Bisulphuret of copper and sulphuret of zinc: *b*, comb of quartz; *c*, wall of indurate argillaceous matter; *d*, comb of quartz, with blende and copper ore (*f f*) on both sides; *g*, cavity, or vug, in another comb of quartz; *h*, more solid comb of quartz.

The larger portion of the vein-fissure is occupied almost invariably by the gangue or veinstone. This is the earthy or non-metallic portion of the lode or vein, consisting of mineral substances, of which a few are of almost universal occurrence as associates of valuable ores. The principal one of these is quartz, which may be said to be almost never absent entirely from any vein. It occurs in a great variety of forms, usually more or less crystalline, sometimes beautifully so, especially in "vugs," or cavities of the vein. Next to quartz, carbonate of lime is most common, in the form of calcareous spar, sometimes compact and sometimes crystallized, and often passing into brown-spar and dolomite. Fluor-spar and heavy spar are also minerals of frequent occurrence as veinstones. Sometimes these substances form the entire mass of the vein for some distance, either singly or together, and are completely destitute of metallic ores ; but this is not usually the case.

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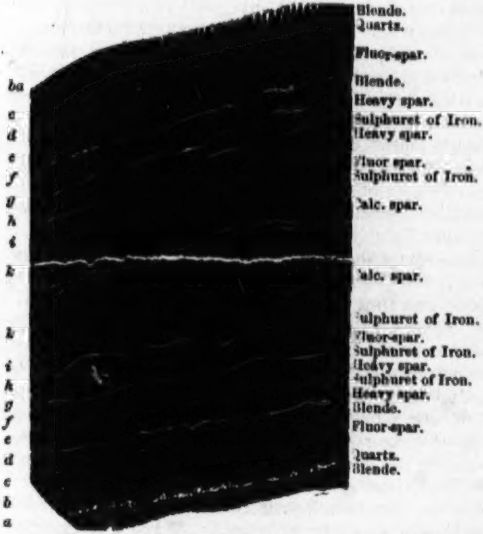
* De La Beche's Geo. of Cornwall, p. 340.

These appearances indicate a long-continued chemical action, occasionally broken off and then renewed ; the materials held in solution within the space of the vein, or gradually segregating from its walls, varying in character at different times. Sometimes a fissure may have been reopened, after having been once filled up with mineral matter, and may thus have afforded space for another deposition of veinstone. There are cases where this enlarging cavity of the vein seems to have been repeated, at intervals, several times in succession, the thickness of each comb indicating the width of the fissure at the time of its deposition, crystallization commencing on the walls as bases, and developing towards the centre, until the whole space was filled up.

In other comby lodes the width of the fissure remained the same, and a succession of deposits took place against its sides, the nature of the material varying at different periods, so that a section of the lode shows a series of various mineral substances arranged in corresponding parallel layers on each side of the centre. A beautiful instance of this mode of filling a vein-fissure may be seen in the annexed figure (Fig. 7), from Weissenbach's

Fig. 7.


Blende.
Quartz.
Fluor-spar.
ba
Blende.
Heavy spar.
c
Sulphuret of Iron.
d
Heavy spar.
e
Fluor spar.
f
Sulphuret of Iron.
g
Calc. spar.
h
i
k
Calc. spar.
Sulphuret of Iron.
k
Fluor-spar.
Sulphuret of Iron.
i
Heavy spar.
Sulphuret of Iron.
h
Heavy spar.
g
Blende.
f
Fluor-spar.
e
Quartz.
d
Blende.
c
b
a

Fragment of the Drei Prinzen Spat Vein, near Freiberg.

Illustrations of Remarkable Vein-phenomena, which represents a fragment of the "Drei Prinzen Spat" Vein, near Freiberg, in Saxony. Next to the walls, on each side, is a crystallized deposit of blende (*a a*); to this succeed layers of quartz, followed by others of flour-spar, sulphuret of iron and heavy spar, as indicated in the figure, each comb on one side having one exactly corresponding on the other, while the middle portion is occupied by crystallized calc. spar, with a cavity in the centre, the whole showing eleven symmetrical repetitions of six different mineral substances. Such perfect symmetry is, however, not often met with, and frequently the whole mass of the vein seems to have been formed by one uninterrupted process.

Every mineral district seems to have certain veinstones; as well as ores, in a measure peculiar to itself, and the locality of an ore may frequently be recognized by a simple inspection of a fragment of the accompanying gangue.

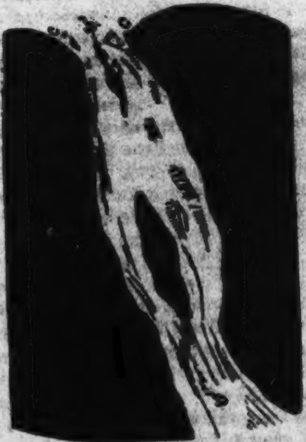
Besides the veinstones proper of a lode, there are frequently found enclosed in it, fragments of the adjacent strata or wall-rock, which have been introduced mechanically. These may have fallen in, in some cases, from the surface, or in the formation of the fissure the rock may have been crushed and broken into fragments, which have afterwards been cemented together by the gangue, so as to form a brecciated vein. The fissure itself is frequently of a complex character, forming parallel branches and sending out ramifications from the main line of fracture. Sometimes these strings are so numerous and irregular that the main fissure becomes lost, and can no longer be recognized by the miner. When a large mass of the wall-rock is thus enclosed between the branches of a vein, it is called by the miners a "horse," or the vein is said to "take a horse." The vein-fissure is sometimes abruptly contracted, so as to show nothing more than a simple crack; in this case it is said to be "nipped." The branches which leave the main lode are called "droppers," and when they concentrate or fall into it again they receive the name of "feeders." The direction and appearance of these off-shoots are closely watched by the miner in opening an untried vein, and from them he forms an opinion as to what parts of the lode are likely to prove richest in ore.

The mass of the veinstone is usually separated from the wall, by what are called selvages (French *salbandes*; German, *saalbander*). These are usually thin bands of clayey matter, and are of importance, since they prevent the adherence of the lode to the wall-rock, and of course facilitate its removal. The walls of the vein themselves are frequently smoothed and striated, as if there had been motion of the lode on its wall, accompanied by pressure; these polished surfaces are called slickensides.

The annexed ideal section of a part of a vein (Fig. 8) will serve to convey an idea of the various technical terms used in speaking of a vein, and its connection with the rock. Cornish miners having been first and most extensively employed in this country, their terms have been generally adopted, as they are in England, from the fact that Cornwall is the most extensive mining district in that country.

It has already been noticed, that the metalliferous portion of a lode or the really valuable ore, makes up, usually, but a small portion of its contents. The barren or worthless mineral substances extracted from the lode and from the adjacent rock, in the process of removing the vein, are called *deads* or *attle*. But few veins are sufficiently rich throughout the whole extent of the mine in which they are worked to allow of their being removed entirely. Frequently a large part of the lode is left standing, or unexcavated, while only the rich bunches of ore are taken out and raised to the surface. The occurrence of these rich deposits of ore in a vein is a matter of great uncertainty, and can only be judged of by the miner, after a careful observation of the district in which he is working. Some varieties of rock, or strata of peculiar mineralogical character, may be found in certain districts particularly rich in ore; and in such cases the

Fig 8.



Transverse section of a vein.

a a, Country; *b b*, Vein; *d*, Hanging wall; *e*, Foot wall; *c c*, selvage; *f*, Vug; *g*, horse.

right kind of country will be sought for by the miner, and the workings on the veins developed to as great an extent as possible in that rock. In other regions, when there are numerous parallel or similarly situated veins, the run of the courses of ore (their situation in regard to the vein) having been determined in one case, the same rule may be found to apply to others. The differences in the character of two rocks, one of which may be highly favorable to the development of a rich lode, and the other just the contrary, are often not of a kind to be easily expressed in words. Long practice, and a well-trained eye will be required, to decide at once which presents the most favorable appearance. Nor does the same rule seem to hold good in different districts, for the formation which in one is productive, will sometimes be found barren in another. Hence miners, with certain fixed ideas, derived from the observation of a limited district, are apt to be led entirely astray, when they insist on applying the same rules to another mining region.

Since the crevices occupied by veins have resulted from the dislocations of the rocks in which they occur, and since their formation has not been confined to any particular epoch, it follows that there may be in any one formation a variety of fissures of different ages and directions. This is found to be the case in many important mining regions, and the phenomena resulting from their influence on each other are often of great interest. The direction of a vein may sometimes be altered suddenly by a change in the course of the fissure, without being heaved out of its course, as it is termed, by the intersection of another. Thus, in the annexed cut

Fig. 9.

Section of a vein at Holzappel.

(Fig. 9), which represents a transverse section of a vein at Holzappel, in Baden, where the vein coincides in dip with the strata, and has been shifted from one plane to another, a distance of twenty-five or thirty feet, without any dislocation having taken place in the rocks. The fissure still connected the two portions of the vein, but was so indistinctly marked that the level was driven through it, as shown in the figure, without its having been perceived; and it was only found again by sinking, when it was struck, having the same characteristics as before.

In a similar manner a true fissure-vein may at some part of its course seem to coincide with the dip of the strata and actually send out branches which follow the lines of dip or cleavage; and yet the main fissure may pursue its course across the lines of bedding, although only cutting them at an acute angle, as represented in the section (Fig. 10). In such a case it may not be possible, without sinking upon the lode for some distance, to ascertain its real character as a true vein. The branches which are parallel with the stratification may be regarded as occupying fissures subordinate to the main one, which have been opened along the line of easiest fracture.

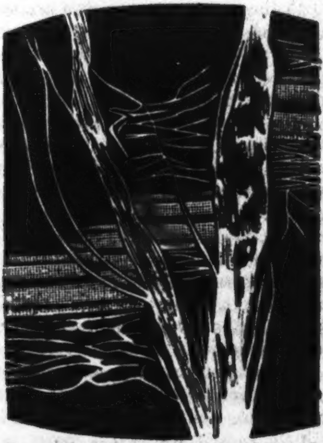
Fig. 10.

Veins sending out branches, which coincide with the bedding of the rock.

The derangements caused by veins of different ages and directions crossing are of great interest. If a vein traverses an older one it interrupts its continuity, and frequently heaves it to one side or the other. Two systems of veins thus crossing each other, may in their turn be both intersected by a third and still newer one, which may heave the other two. Instances of this kind are common in mining districts which have been subject to frequent dislocations. The newer vein intersecting an older one at a considerable angle is called a "cross-course," or contra-lode ; the latter name being usually applied to the intersecting vein if it contain valuable ores. In Cornwall, there are several systems of fissures, producing in many instances a complicated shifting of the veins. The general parallelism of veins of the same age is remarkable in many parts of that region, and generally in all districts where there are numerous fissures of different ages; It is also noticed that contemporaneous veins are not only parallel with each other, but that they usually contain the same varieties of ore associated with similar veinstones. In the Harz, there are two principal directions of fracture; the Samson, the most powerful lode of the district, cutting and heaving the Gnade Gottes and Bergmann's Trost, two other important veins. The most interesting and complicated phenomena of the intersection of numerous systems of veins are presented by the Freiberg district in Saxony, where extended mining operations have been carried on for a great length of time, and have been studied by a skillful corps of mining engineers and professors attached to the School of Mines at that place. More then nine hundred different veins have been recognized within a space ten or eleven miles in length, by four or five in breadth. They are grouped by Weissenbach into four classes, according to the nature of their gangues; each of which is also in some measure characterized by certain ores, and by a constant direction.

In this country there have been no such complicated phenomena of veins of different ages observed. In the rigion to which most properly the term mining district may be applied, namely, that of Lake Superior, there are numerous veins, but they do not afford evidence of more than one epoch of formation. In any limited district, as for instance, that of Keweenaw Point, the veins are nearly parallel with each other, and are not intersected by cross-courses which heave them from their course. In a few instances there seem to have been slips of the various beds of rock upon each other, which have shifted the veins at the junction for a few feet to one side or the other. In the Southern States the metalliferous deposits usually lie in the direction of the stratification, belonging to the class of segregated veins, and are not crossed by any fissure veins. It will not therefore be necessary to go into any lengthy description of the particular appearances attendant on such intersections, especially as they differ much in different districts. In general, however, the crossing of two veins is wont to be considered as advantageous to the production of ore at that spot, and rich bunches of mineral are looked for by the miner at their intersection, especially if the angle at which they meet is a small one. Sometimes one lode impoverishes the other for some distance, carrying all the ore with it. As an instance of this appearace presented by two lodes intersecting each other, the annexed

Fig. 11.



Ground plan of the intersection of veins in the Himmelfahrt mine, near Freiberg.

cut (Fig. 11) is given, representing one lode crossing another as sketched by Weissenbach.

Theories of the Formation of Mineral Veins..—Although a full discussion of the various theories of the formation of the metalliferous deposits would occupy much more space than can be given to the subject in the present work, yet it will not be out of place to notice briefly some of the most important theoretical considerations which the study of vein-phenomena suggests. The following are the principal heads under which the theories which have been proposed may be arranged.

1. The veins originated contemporaneously with the rocks in which they are contained, and are, so to speak, a mere accidental phenomenon, not governed by any fixed laws of formation. This theory may be dismissed at once, as entirely at variance with all the facts, and as unworthy of consideration.

2. Veins have originated in the filling of fissures, by injection of metallic and mineral matter in a state of igneous fluidity from below. This is the theory usually adopted to account for the phenomena of the veins of so called igneous rocks, such as granite and trap ; which like modern lava, are supposed to have been once in a plastic or semi-fluid state, under the influence of a high temperature, and in such condition to have invaded the superincumbent rocks, being forced into the crevices by upward pressure. However such a theory may adapt itself to the Plutonic veins, it cannot be considered as explaining the modes of formation of metalliferous lodes. It fails to account for, or rather is contradicted by, the often observed fact, that the character of the lode changes with the rock in which it is found, being rich in ore in one formation, and barren in another adjacent

one. This could not have been the case if the vein had been forced up through the strata, as the nature of the rocks through which it was raised could have had no influence on its contents, the action being but momentary and mechanical. Besides, if we consider the immense force which must have been required for such an upward motion as this theory supposes, it will be apparent that, had it really taken place, evidence of its existence must have remained in the widening out of fissures in depth and in the shattered condition of their walls; while there would have been a constant tendency in the more valuable metalliferous substances, being heavier than the veinstone itself, to occupy the lowest position in the vein. Such phenomena, however, have only been observed in isolated cases, while usually the appearance of the walls and the distribution of the mineral matter and ore between them in true metalliferous veins, is such as to make this hypothesis of their formation entirely untenable.

3. The theory of formation by sublimation, according to which vein-fissures were filled by the volatilization of metallic matter from the great centre of chemical action beneath, namely, the ignited interior of the earth. That such might have been the origin of some metalliferous deposits, and that this agency may have contributed in some degree to the filling of veins, cannot be denied. The fact of the volatility of some metallic combinations is well known, and can be observed at the present day in the products of volcanic ejections. Evidence of the same character is afforded, in some instances, by the position of metalliferous particles on the under side of crystals lining the walls of a lode; as, for instance, Nagyag, in Transylvania, where metallic arsenic is seen to have

been sublimed and deposited on those faces of crystals of manganese-spar which were turned downwards. Specular iron is found sublimed into the fissures of volcanic craters, and sometimes carried to a considerable distance and deposited. But these phenomena are of limited extent, and not by any means sufficient to account for the existence of the masses of ore and of earthy minerals filling the body of a large vein. Neither would such a theory account for the variation in the character of lodes in passing from one rock to another, nor for the presence in them of substances not volatile in their nature, nor for any of the complicated phenomena exhibited by veins in their intersections with each other. Hence we must conceive that the agency of sublimation was of very secondary importance in the formation of metalliferous veins. In contact deposits and some irregular forms of occurrence, where the whole mass of a bed seems to have been impregnated equally throughout by metallic particles, as especially exemplified in some mercury mines, we can conceive of no theory more probable than that of the diffusion of the metallic matter through them by sublimation. Thus originated the extensive beds worked at Almaden, so rich in mercury ; and they offer the most striking example which can be given of the class of deposits to which this theory may be applied.

4. The theory proposed by Werner, which may be called that of aqueous deposition, presupposes a chemical solution covering the region in which the veins are found, from which solution, by chemical precipitation from above downwards, the vein matter was accumulated in the fissures existing in the rocks below. This theory is in direct opposition to that of igneous injection, since, according to its principles, the origin of the

contents of veins was a superficial one, their introdution into the fissures from above instead of from below, and the action a chemical instead of a mechanical one. But in the sense in which this mode of formation was understood by Werner, but little importance can be attached to it. If any such fluid holding metalliferous substances in solution had actually covered the surface, we can conceive of no reason why it should have deposited its contents in the fissures rather than on the surface adjacent; and we ought in accordance with his ideas, to find every vein connected with a flat sheet of metalliferous ore somewhere along its course, at the place which the solution occupied in the series of formations at the time of the filling of the vein-fissure. Such, however, is not the case, at least in regard to true veins; although there may be a limited class of mineral deposits to which this theory will apply. Besides, if depositions in veins took place in this manner, we should expect to find more or less matter introduced at the same time, mechanically, and showing its origin by its stratified condition. There is nothing of this kind however observed in true veins. The deposits all took place in a direction parallel to the walls, and not horizontally, as they would have been in part, under the circumstances required by this theory. There are many other reasons equally conclusive against the ideas of Werner ; but it is not necessary to enter into them at length, since his theoretical views with regard to the origin of veins have ceased to have the weight which was once attached to them.

5. The theory of lateral secretion. The views which are at present most generally adopted, assume a somewhat complicated series of phenomena as concurring in the formation of mineral veins. It cannot be doubted

that the process has been a complex one, and one requiring a long period of time for its development. No one simple cause can be considered sufficient to account for all the facts, but the main idea is that of lateral secretion, or segregation of the mineral and metalliferous particles from the adjoining rocks in a state of chemical solution, and their deposition upon the sides of a previously formed fissure under the influence of electro-chemical forces.

This is the only theory which will account for the often noticed fact of the change in character of a lode in passing from one geological or mineralogical formation to another of a different character, and it seems to be more in accordance with the other phenomena of veins than any other one yet proposed.

The metallic appearance of the most common ores and their resemblance to certain well-known furnace products, are apt to lead to the supposition that they must be exclusively of igneous origin, especially in view of the fact that the mineralizing substances with which the metals are generally found combined are such as have the effect of rendering them more volatile. Nor can it be denied that some ores and metals do occur in rocks of undoubted igneous character in such a way that they must have had an origin contemporaneous with that of the mass in which they are disseminated. But these deposits do not belong to the class of regular veins, in general, but are to be classed, as already shown, among the irregular modes of occurrence. The metalliferous substances produced artificially, and found filling cracks and cavities in connection with furnaces, and in the chimneys of smelting-works, do not seem to possess that comby structure, or parallel arrangement so characteristic of true veins. If metalliferous particles were introduced into a vein-fissure by sublimation, they would naturally rise and be condensed together in accumulated masses, which might have a crystalline structure, but would be distributed in such a manner as to show their igneous origin.

On the other hand, we know that the earthy substances forming the gangue of metalliferous lodes, and usually far predominating in quantity over the ores themselves, are not the products of igneous action. The minerals which form the mass of the trappean rocks and of volcanic lavas, such as the feldspar family, hornblende, augite, olivine, and the like, are not the usual components of the veinstones, as we should suppose would have been the case, were the veins in which they occur the result of igneous action. On the contrary, we know that the usual gangue minerals, quartz, calcareous spar, and heavy spar, according to the researches of Bischof, and other eminent chemists, cannot possibly have been introduced into vein-fissures by injection while in a state of igneous fluidity, or by sublimation. We know also that some of the ores accompanying these veinstones undergo decomposition at a high temperature; and many of the most common, such as sulphurets of iron and lead, we see in constant process of formation in aqueous solutions, at the present time. The sulphuret of iron is one of the most common products, where ferruginous waters are brought into contact with decaying organic matter; and it is also one of the precipitates from hot springs. It has been shown by Murchison that the copper ores of the Permian strata of Russia must have originated in a similar way, since they are accumulated around and on the surface of the carbonized remains of the stems and branches of plants.

Fissures being opened far down into the heated interior of the earth, they would become filled with water charged with various kinds of mineral and metallic substances. In their passage through rocks of various characters these solutions would be variously acted on, and would, under hydrostatic pressure, penetrate more or less deep into the surrounding strata, according to their texture and other circumstances. If the water was acidiferous, it might thus combine directly with metalliferous particles previously existing there.

There can be no doubt that the contents of a vein-fissure have often acted chemically upon the adjacent rocks, since it is very frequently found that the walls have undergone a great change for a considerable distance from the lode; often the country is found decomposed and rotten, its texture being entirely destroyed; or it is impregnated with silicious matter, so as to be much harder and more quartzose than at some distance from the lode. These hardened silicified masses are called by the Cornish miners the *capels* of the lode.

Under the presupposed circumstances, it is evident that a fissure being filled with solutions thus originating, there would be ample reason why there should be deposits of ore within the limits of certain strata, in preference to others. Either those beds might themselves contain more metalliferous substances, which would enter into solution, to be again deposited within the walls of the fissure, or there might be something in their structure which would enable them to act with more efficiency in decomposing the solutions brought from other sources, by circulation of the column of water filling the cavity of the vein.

We cannot doubt that electro-chemical action is, and has been going on in mineral veins, and that the explanation of many of the more obscure facts with regard to the distribution of the ores within them is to be found in this all-pervading agency.

Mr. Robert Were Fox seems to have been the first to be impressed with the idea that electric currents might "not only contribute to produce the extraordinary aggregation, and position of homogeneous minerals in veins," but that the action was still kept up in them, and he instituted a series of experiments in the Cornish mines for the purpose of determining this fact. He found the mine-waters to be impregnated with a variety of salts, but in very different proportions in different parts of the same mine. He also found by numerous experiments that the reaction of these solutions on each other, and their contact with extensive surfaces of rocks of different characters, gave rise to electrical currents, the effect of which was to promote decomposition and deposition of various mineral substances, similar to those found occurring in veins. He thus was enabled to account for some of the most curious facts in relation to the position of the ores in the Cornish mines. Professor Reich, in the Freiberg mines, arrived at similar results, and Mr. Robert Hunt also made numerous experiments, determining the existence of galvano-electric currents in the veins of Cornwall, and producing chemical decomposition by their aid. He arrived at the conclusion that these currents were purely local in their nature, originating in the decompositions going on in the vein itself, and not connected with the great magnetic forces which sweep around the earth.

Whether or not it be allowed that these electro-chemical currents performed a very important part in the original formation of veins, it cannot be denied that in the chemical changes which have taken place in the upper portions of metalliferous lodes, and which are evidently still going on, they were and are conspicuous agents. These changes of character are well recognized in all mining districts. They are usually indicated on the surface by a discoloration of the lode by oxide of iron, and a general rotten appearance of the veinstone. The Germans call this the "iron hat" of the vein, the Cornish give to it the name of "gossan."

In the cupriferous lodes of Cornwall, the normal ore, below the point to which decomposition has reached, is copper pyrites, or sulphuret of iron, and copper, and other sulphurets of copper. But near the surface the metalliferous ores, instead of sulphurets, are oxides and oxidized compounds, such as silicates, carbonates, and phosphates. Often a large portion or all of the copper near the surface has been removed, having been oxidized to sulphate of copper, and dissolved out and washed away, leaving the iron mixed with the quartzose veinstone, in the form of a hydrated oxide or gossan. Similar appearances are presented by lodes containing lead ores; the sulphuret of lead, or galena, which is almost the only ore found in any considerable quantity at some depth, being, near the surface, converted into a great variety of oxidized combinations, of which the carbonate, sulphate, and phosphate are the most common.

In general, this zone of decomposition does not reach much below one hundred feet, but in some instances it penetrates to the depth of three hundred, and there are, on the other hand, veins in which no such chemical changes have taken place, the original sulphurets existing undecomposed almost at the very surface. The causes which have operated in accelerating and retarding these transformations are not quite clearly understood. Bischof has shown that heated steam has been one of the most powerful agents in the decomposition of the contents of veins, and that it has been most effectually aided by carbonic acid.

In order to prove this he subjected sulphuret of lead, while heated, to the influence of a current of steam, which reduced the galena to metallic lead, the sulphur passing off in the form of sulphydric and sulphurous acid gases.

Sulphuret of silver is reduced in the same way, the resulting metal taking that dendritic form which it commonly has in its associations with the ores of lead and silver. The reduced metals thus set free, if they belong to the oxidizable class, are then ready to enter into combination with the various acids everywhere being liberated under electro-chemical agencies. No doubt the effect of atmospheric influence is to be largely taken into account also, since these changes are principally superficial only, compared with the total depth to which the ores are found to extend. The penetration of water charged with oxygen into the fissures and minute pores of the rocks must be in some degree essential to these processes. To give any idea of the complicated changes thus slowly taking place in many lodes, would require far more space than the object and scope of the present work could permit; it is sufficient here to have indicated some of the causes at work in the formation of mineral veins.

The variations of the metalliferous portions of lodes at different stages are of the highest importance to the miner not only in relation to the changes which the ores have undergone near the surface, but as viewed in connection with their persistence in mines worked to great depths. In this country we have hardly more than begun to open our mines, so that we have but little more than superficial indications to judge from; but in the mining districts of Europe, which have been wrought for centuries, there are abundant data accumulated to enable us to draw some important conclusions in regard to the termination of veins in depth. The distinction between true veins and all other forms of occurrence of ores must be carefully studied in reference to this question, or otherwise it will be difficult to obtain a clear conception of the truth. The facts may be briefly summed up thus:

1. True fissure-veins are continuous in depth, and their metalliferous contents have not been found to be exhausted, or to have sensibly or permanently decreased, at any depth which has yet been attained by mining.

2. Segregated and gash-veins, and the irregular deposits of ore not included under the head of veins and not occurring in masses as part of the formation, cannot be depended on as persistent, and they generally thin out and disappear at a not inconsiderable depth; at the same time they are often richer for a certain distance, and contain larger accumulations of ore, than true veins, so that they may be worked for a considerable time with greater profit than these, although not to be considered as of the same permanent value.

THE GENERAL PRINCIPLES ON WHICH THE CONTENTS OF A VEIN OF MODERATE WIDTH ARE REMOVED.

In order to render the descriptions of mines and mining operations in the succeeding chapters more intelligible to those who have never given their attention to these subjects, in is proposed to add a few pages on the general principles of exploitation; by which term is understood the process by which ores and minerals of value are won from their natural position, often at great depths below the surface, and brought where they can be rendered available. Those who are not acquainted with the nature of such operations, and who have never had occasion to reason on the many circumstances which must be taken into consideration in laying them out, frequently suppose that a mine is a mere excavation in the ground without law or rule, and that this, which would seem to them to be the simplest method, would be also the best for such a work. Nothing can be farther from the truth; for to open a mine, if on a vein or regular deposit of ore, and work it as an excavation open to the air, or as an "open-cut," is quite impossible, if it is necessary to go below the most moderate depth. And such is the case with metalliferous lodes, the superficial portion of which, for some distance down, is often less valuable than that below, and sometimes of no value at all. Moreover the richest part of a vein is usually of limited extent, and its treasures can only be won by penetrating into the earth to great depths. To raise the ore from such a distance beneath the surface, requires powerful machinery which must be placed on firm ground directly over the vein. The surface-water and rain must be kept from running into the excavations, which could not be done were they opened throughout to the day; and as the freeing of a mine from water is one of the most expensive operations connected with its working, the greatest care should be taken to get rid of as much as possible in the simplest and least expensive manner.

Again, it is necessary that mining should be carried on uninterruptedly by night and day, and in all weathers, since only a limited number of persons can be usefully employed at one time; also that a system of ventilation should be kept up; all of which would be impossible, were the excavations exposed to the weather, or the mine made to consist of a single open cavity.

The first operation in opening a mines is usually to remove the surface-water, by driving an *adit-level* or horizontal gallery, which shall commence in an adjacent valley, at the lowest point not liable to inundation and conveniently accessible, and thus drain all that part of the proposed work which lies above.

Fig 12.

Transverse section of a shaft and adit-level.

Figures 12 and 13 illustrate the position and object of the adit-level. In extensive mines large sums are frequently expended in thus getting rid of the water; sometimes a number of mines are drained by a simple adit of great length driven at their joint expense, or that of the State, when the work is of great magnitude. So long as the excavations in the mine are kept above the level of the adit, no machinery for pumping is required; and when extended in depth below it, the water is elevated by the pump or other contrivances employed,only up to that point; thus, in a very extensive mine, every foot through which a large body of water is to be raised, which can be saved, is of importance, and large sums of money may be economically expended in obtaining even a small reduction of the distance.

Frequently only a few feet of "back," as it is called, or of perpendicular height above the adit-level can be obtained; but in other cases, by an adit planned with judgment, several hundred feet of drainage may be obtained, so that mining may be carried on for a long time without the expense of costly machinery for pumping. If possible, the adit should be driven on the vein, or by the side of it, so that its character and richness may be ascertained by breaking into it occasionally as the work progresses. A large number of the Lake Superior mines are thus favorably situated; and extensive drainage may be had at the same time that the vien is proved in depth.

If sufficient advantages present themselves for the location of machinery for washing and dressing the ores at the mouth of the adit-level, they may be brought out on a tram-road laid in the level, and the necessity of hoisting them to the surface by machinery may be thus obviated. If the adit-level cannot be excavated *on* the vein, it must be driven *to* it, as represented in Fig. 12, and the levels are then to be extended on it right and left.

In a region where the veins run in a direction parallel with the range of elevations, it will generally be necessary to drive the adit-level through the "country;" but if the vein cross the ridges at an angle, it will also cross the nearest valleys on each side of the elevation, and may be worked from one side or the other. In the majority of cases,however, the adit-level is only used to remove the surface-water, but few mines being so favorably situated as to have a very largeportion of their work above it.

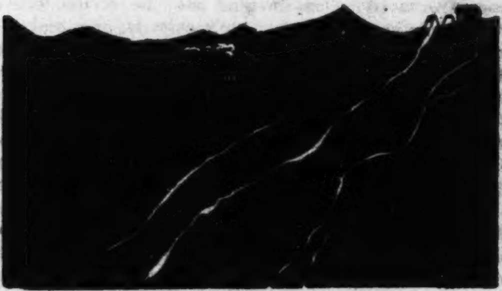
As the necessity of ventilation would not allow the adit-level to be driven to an indefinite distance without some communication with the surface, so as to establish a current of air through it, it becomes necessary to commence excavations on or near the line of the veins, which may intersect the adit, or a cross-cut or level leading from it, and which are carried down to a still greater depth for the purpose of opening and working the mine. These excavations whether vertical or inclined are called shafts. Their inclination depends on a variety of circumstances, such as the underlay of the vein, or the angle which it makes with the perpendicular, its width, or the nature of the rock in which it occurs.

If the vein approach a vertical position the shafts are usually sunk upon it, unless its underlay is so irregular as to spoil the shaft by making it too crooked, in which case it is sunk by the side of the vein, and connected with it by cross-cuts. In Fig. 12 a shaft thus sunk on a vein of generally regular underlay is represented. Whether a shaft shall be sunk on the vein, so as to include the vein within it, or by the side of it, is also de-

endent on some other circumstances. If the lode is
vide and the veinstone such that it can be wrought with
s much facility as the adjoining rock, it is best to sink
n the vein itself, especially when its dip is nearly verti-
al, and the country solid, so that little ground need be
eft standing in the lode to support the walls, and pre-
erve the shaft. In the mines of Lake Superior this
nethod is generally followed.

If the vein has an underlay as great as forty-five de-
grees, it is a matter of some importance to know whe-
ther it is best to work the mine through shafts inclining
with the vein, or by vertical shafts connecting with it by
cross-cuts. The latter method is illustrated by the an-
nexed ideal section (Fig. 13). In such a case a shaft is

Fig. 13.



Ideal section of a system of shafts for opening a mine on several parallel lodes.

commenced at some distance from the lode, in the di-
rection from its outcrop towards which it dips, and sunk

perpendicularly until it cuts the lode, at a point the depth of which can be calculated if its dip is known. After intersecting the lode it may be continued below it, and cross-cuts must be driven as before at suitable distances, so as to open a sufficient number of points for working. If there are several different lodes within a small space, as represented in the figure, or if it is desirable to make underground explorations for veins not supposed to appear at the surface, the method of sinking vertical shafts is to be recommended.

In the English mines the practice of sinking shafts inclining with the lodes has not generally been adopted; although, when it can be done, it presents some great advantages over the other method, a large amount of unprofitable excavation in the rock, or *dead-work*, as it is called, in cross-cutting from the shaft to the lode, being thus saved. This method may be recommended when the dip of the lode is tolerably regular and the rock solid, and where there is only one vein to be worked through the same shaft. In order to raise the ore in such a case with advantage, a double tram-road should be laid in the shaft, and the ore hauled up in cars which run from the levels directly on to small platforms, mounted on wheels, on which they are raised to the surface. In the Lake Superior Region there are numerous veins underlaying from 40 to 50 degrees, the shafts are invariably carried down on the lodes, and no practical difficulty experienced: on the contrary, it has proved the most economical and judicious method under the circumstances. In the Southern gold mines, where the rocks are frequently decomposed and softened, so that for the first fifty to one hundred feet sinking costs but little, the shafts are generally vertical. Of the gold regions of the Pacific coast the same may be said. If the underlay of the lode is very irregular, it is better not to sink upon it, as crooked shafts present many disadvantages in fitting up the machinery for pumping, tram-roads, and other requisites.

The dimensions of a shaft are variable, and dependent on the work to be done by its aid; when it is to be used for winding up the kibbles, or buckets of ore, and at the same time as an "engine shaft," or the shaft in which the pumping machinery is placed, it should be from twelve to fourteen feet long, and is usually from six to eight feet in width. Shafts which have been timbered up for the whole, or a portion, of their length, are square or rectangular; those which are built up with stonework are usually round.

In this country, wood is universally used for this purpose, timber being usually cheap and abundant in our mining districts. In the Lake Superior region, the shafts only require to be suported for a few feet, or until solid rock is reached. The timbers are squared roughly, and laid upon each other, forming a substantial framework, which rests in a bed-place cut in a rock where it is sufficiently solid to obviate any danger of its giving way.

For a distance of fifty feet, or even one hundred, if desirable, the ore and rubbish may be raised to the surface by the simple windlass, worked by hand, on which a rope is so wound that one bucket or kibble descends while the other ascends. The same means are used in sinking a "winze," or excavation from one level to another, not extending up to the open day. As soon, however, as the depth of the shaft becomes more considerable, it is necessary to resort to horse or steam-power for raising the ore. The common machine used for this purpose is called a whim; as usually constructed when worked by horse power, it is represented in the annexed cut (Fig. 14). In the steam-whim, which is generally used when the shaft has a depth of more than two hundred feet, the cage or drum on which the rope or chain is wound is usually placed horizontally, instead of vertically as in the common horse-whim. Frequently, in opening a mine, before the excavations have reached any considerable depth, the pump-rod is attached to the whim, and worked by the same power which raises the ore.

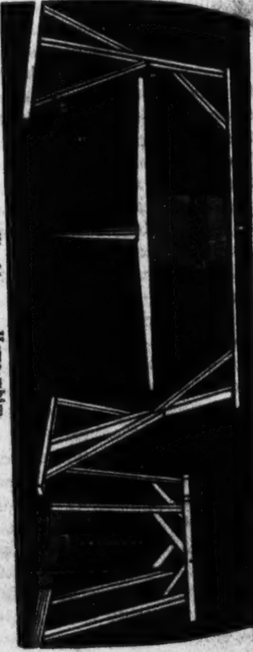


Fig. 14. Horse-whim.

The steam-engine is not usually applied to working a mine, until there is good reason to suppose that it may become of permanent importance. For hoisting ores, no very great power being required, small horizontal high-pressure engines, working full steam, are usually employed. The machinery must admit of instantaneous reversal, and should be as simple aspossible. Water-power, if at hand can be advantageously applied to the same purpose. The pumping-engines in extensive mines are usually low-pressure ones, and every effort has been made in Cornwall and other mining regions to reduce the consumption of fuel to the smallest possible amount, by perfecting the form of the boiler and machinery.

Most mines, when worked to any considerable extent, have several shafts; two, at least, are almost necessary for ventilation. The distances from each other at which they are located depend on a variety of circumstances, such as the nature of the surface, the distribution of ore in the vein, and the extent of the sett or length of the vein which can be worked. Two shafts should not be too near each other, if it can be avoided, as in that case the blocks of ground would be too short, causing a wasteful expenditure in opening the ground. If far apart, winzes must be sunk between them, in order to afford ventilation and the means of attacking the vein at a sufficient number of points. In general, three hundred feet distance between two shafts, in a vein of moderate width and richness, may be considered reasonable.

After the shaft has been sunk to a proper depth, if on the vein, drifts or levels are commenced from it in each direction, so as to open blocks of ground, as they are called, or portions of the vein, which are thus rendered accessible so that their contents can be removed. The Cornish miners usually arrange the drifts so as to leave between them a back of sixty feet or ten fathoms; that is, one level being started, the shaft is continued sixty-six feet (six feet being allowed for the height of the drift), and then another level is commenced, leaving a portion of the vein between them sixty feet in height. Like the shafts the levels may be driven in the vein itself,

or by the side of it, according to its width, texture, an
other circumstances.

The contents of a block of ground thus prepared ar
removed by what is called *stoping*, or working in step
the object of which is to take out all that portion of th

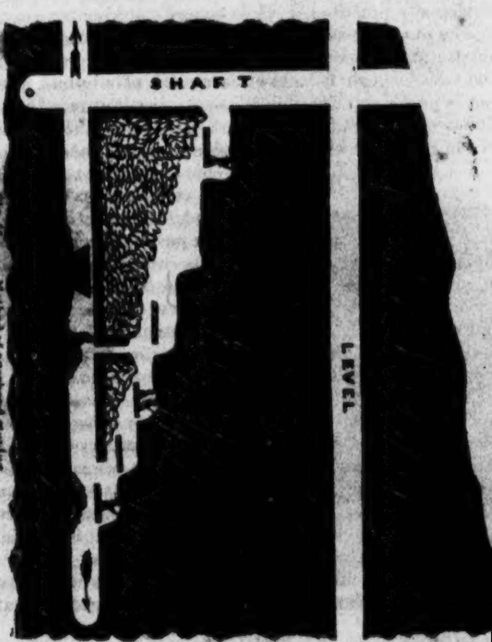


Fig. 15. Method of overhand stoping

vein which is worth reserving for its ore. There are two methods of doing this, one of which is called overhand and the other underhand stoping, the difference being, that by the former method the vein is taken down by working from below upwards, in the other by excavations from above downwards. Overhand stoping is almost universally practised in this country.

The annexed section (Fig. 15) will illustrate this method. It represents a supposed longitudinal section, on the vein, of a shaft and two levels, between which stoping is going on. The rubbish which is necessarily blasted down with the valuable part of the vein, is piled up back of the miner, as his work proceeds, on a scaffolding of stout timbers, called *stulls*. At suitable distances openings are left through the rubbish called *mills* or *passes*, through which the ore is shot down to the level below to be loaded on to a wheelbarrow or car, and conveyed to the mouth of the drift, or to the shaft, to be hoisted to the surface. The rubbish accumulated in the space from which the vein has been removed serves to support the walls and keep them from coming together. The annexed cut (Fig, 16) shows, in a transverse section, the method of supporting the rubbish and the floor of the level beneath. The workman, while engaged at stoping, stands on a platform laid on stulls, as indicated in Fig.

Fig. 16.

[illegible] in a mine.

15 above. Stoping upwards is the most rapid and economical method, when the ores are not very valuable, or difficult to distinguish from the rubbish. Of course, in working from below upwards, the looseness and working away of the rock is aided by gravity, the fragments tending downwards by their own weight, and it is therefore easier for the miner; but, on the other hand, as the rock and ore are thrown together by each blast upon the pile of rubbish below, it requires care, on the part of the miner, to select out the valuable portion of the lode without sending up too much of the worthless rock, which, apart from the cost of hoisting it to the surface, is needed to fill up the space left by the previous excavations, in order to help to support the walls.

Exploitations of Thick Veins and Masses.—When the deposit of ore to be mined is in masses, or veins of extraordinary width, the process of removing their contents becomes a more difficult one, especially if the surrounding rocks are not firm and unyielding. The general method, however, is the same: the work must be subterranean and not open to the day. One or more shafts must be sunk into or near the mass to be removed, and the work commenced at as low a point as possible. Levels are then driven into the ore, and as fast as the valuable mineral is removed, the rubbish which is made is piled up in its place, so as to support the portion left overhead. If there is not enough material for this, stones must be sent down from the surface. In this way the whole contents of a mass can be removed without loss. The methods pursued in such workings must be especially adapted to the shape of the deposit of ore, the degree of solidity of it and of the adjoining rock, and a variety of other circumstances; the general principles, however, are those above indicated.

Timbering of mines.—We now come to the timbering of mines, an important subject. In Mexico, stringent laws have long been in existence, and are strictly enforced, regulating the size of the pillars of ore, and their distance from one another, to be preserved in each silver-mine for the protection of the mine, and the adequate support of the superincumbent mass. There, these columns of ore preclude the necessity for timbers, but in California it is different. Here, nearly all our mines are auriferous, and instead of the deposit being a huge deep mass of ore, it generally occurs in a single stratum. Besides, the rock is seldom compact enough to form supports.

Perhaps it would be as well if California also had laws regulating the timbering of mines; for the bungling and insecure work of inexperienced timberers has occasioned in many cases great damage to the mines, and even loss of life; and instances are not wanting of large tracts of country, beneath which mines have been or are being worked, suddenly sinking, because the props or timbers were of bad material or shape, improperly or imperfectly adjusted, or unattended to for a course of years and suffered to rot without being replaced by new ones. Thus the houses, gardens and fields above were in a great measure ruined as well as the mines below.

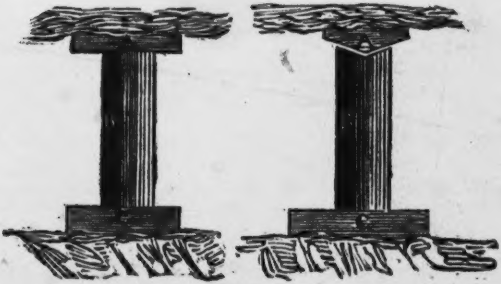
A large amount of wood is of necessity required about a mine, and great care should be taken in its selection. "In some mining regions," says Prof. Whitney, "where it is scarce, its cost becomes one of the most considerable items of expense to be incurred, as for instance, in the Australian copper mines. Cornwall is mostly supplied from Norway; and the timber cut from hundreds of square miles of Norwegian forests is now buried deep beneath the surface in the Cornish mines. In Germany large tracts of forest are set apart for the use of the mining districts; and the wood is cut from a certain portion every year, so that a constant supply is kept up." Were such tracts of timber reserved in this State, perhaps it would be better for our mining posterity.

The timber most commonly used in the mines of California is pine, which grows in great abundance upon the mountains. It is far from being the best kind of wood to use for this description of work, but is the only kind universally handy. It should by all means be well seasoned to avoid shrinkage, and the timbers must be placed pretty close together.

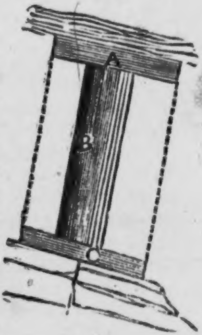
"The timber," says Mr. G. Thurean, M. E., "should be left as round as possible, and be well barked—the former for greater compactness and strength, the latter to prevent rot, which soon takes place in such workings, where the temperature changes, and consequently the air is moist and dry at intervals. The mode in which the various workings are being timbered should admit the repair and exchange of bad and rotten portions without interfering with any of the rest; this will effectually prevent the infection of sound pieces by the bad ones. For this purpose many means and remedies have been tried, out of which the constant watering is the most effectual in the end. This is done through the construction of little spouts in connection with the cisterns and lifts, which then throw little streamlets of water over the timber, causing it to retain all the properties of well-seasoned and sound wood, without augmenting to any great extent the quantity of water to be lifted from the deep evels of the mine. It is well and very desirable, that n the main drives and shafts of a good-conducted mine he same standard measure for timber should be adiered to. By doing so, greater facility for preparing a upply of timber on the "grass" is secured. The fitting s also less difficult, and the working may then be made of such uniform dimensions as will not cause any loss of ime whilst being timbered."

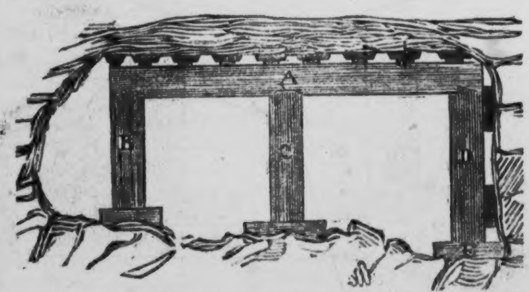
The amount and direction of the pressure in mines an be but very imperfectly estimated, and practical experience is the safest guide. The object of timbering is o meet and resist the pressure with sufficient force, and his must be done at right angles to it.

Underground timbers consist of three pieces, viz: The ap (A), the foot (C), and the prop (B), which may be een in the accompanying cuts. The position and angle of pressure will be seen at a glance in the second

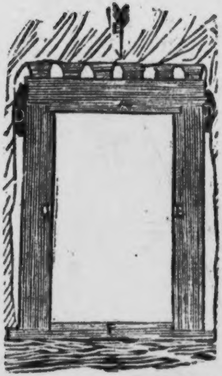


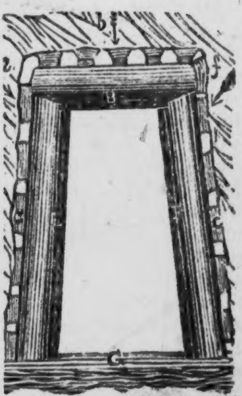
engraving where the timber stands on an inclined plane, from which the auriferous quartz or other ore has been excavated. The first cut gives the position of timbers in alluvial deposits, where there is only one pressure, viz: from above; the second shows how a prop is placed to withstand two. In alluvial workings, the timbers are arranged as in the following sketch, which the reader will readily understand without further explanation. These workings are almost invariably on a level.



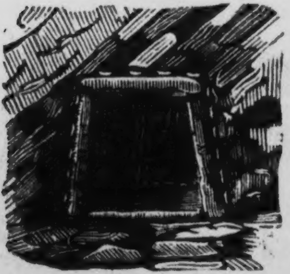


The next sectional engravings exhibit the usual structure of timbering in tunnels and drifts, or "drives," and in these the pressure is shown by arrows:

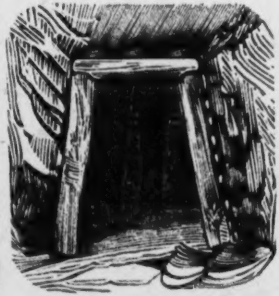


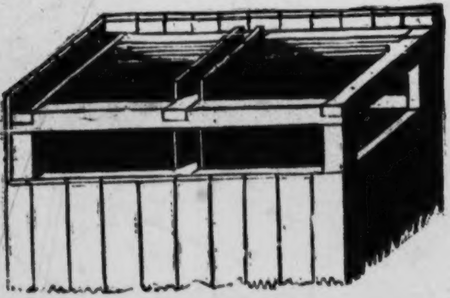


For the purpose of showing the general reader more fully the manner of timbering tunnels in different descriptions of rock, we present two other drawings. The tunnel to the left of the page is run through rock which is soft and liable to "cave" or crush inwards. In this it is necessary to have a foot-piece to brace the timbers apart and resist such pressure, besides having the sides and roof lined with planking. The



other tunnel is supposed to run through ground which on the one side is firm rock, and on the other yielding; so that it is necessary on the soft side to have a plank lining, whilst the rocky side is bare. Prospecting for a lode is often carried on by shafts instead of tunnels. In deep mines too, it is necessary to have air shafts, which are worked from above or below, as the miner may elect, or both ways at the same time. They are, however, mostly worked downwards. In sinking shafts it is often necessary to timber them. Sometimes where the main shaft is used for dirt hoisting, it is double timbered; a dirt-tub being hoisted in one division of the shaft, its fellow is lowered down the other





We present a section of a double shaft, showing the timbering &c. We earnestly recommend that none but thoroughly competent drifters be employed in our underground mines, as half the casualties that occur are occasioned by inexperience in timbering.

Manual of Mining and Metallurgy.

This portion of our work is intended to furnish those who have not the advantage of a large library, with the substance of the researches of eminent miners and metallurgists, and to explain many processes and technical terms and phrases which are frequently not understood.

To form a portable book of reference for those who wish to acquire an additional knowledge of those arts,—a repertory of everything needful for the acquisition of a knowledge of the applications of geological science to purposes of utility.

To be a companion to the practical miner and metallurgist—an invaluable *vade mecum.* To enable the latter to extract, to assay, and to tell the properties of all the useful metals; and to acquant the former with a knowledge of rocks and their order of superposition, by which great assistance in searching for the metals may be derived, and which will give him a clue to the rich depositories of mineral treasures.

An acquaintance with the general results, collected and classified by geology, must be our first guide in the investigation of mines. This enables the observer to judge whether any particular district should, from the nature and arrangement of its rocks, be susceptible of including within its bosom, beds of workable and valuable ores. It indicatesalso, to a certain degree, what substances may probably be met with, in a given series of rocks, and what locality these substances will preferably effect. For want of a knowledge of these facts, many persons have gone blindly into researches equally absurd and ruinous; and an amount of money much greater than is generally known has thus been expended in vain. To attempt anything without it, would be like sending a ship to sea without a helm to direct its course, without sails to catch the impelling breezes, and without a compass to guide its way. Formerly, indications of mines were taken from very unimportant circumstances, but geognostic observation has substituted more rational characters of metallic deposits. They may be called—

1. Negative indications, which are derived from that peculiar geological constitution, which, from experience, or general principles excludes certain metallic matters; *e. g.*, granite, and, in general, every primitive formation, forbids the hope of ever finding within them combustible fossils, such as pit-coal, unless it be beds of anthracite; there, also, it would be vain to seek for common salt. Granite rocks very seldom include silver; or limestone, ores of tin. Volcanic territories never afford any metallic ores worth the working; nor do extensive veins usually run into secondary and alluvial formations. The richest ores of iron do not occur in secondary strata; and the ores of this metal, peculiar to these localities, do not exist among primary rocks.

2. Positive indications, which consist either in an efflorescence of the subjacent metallic masses: as magnetic attraction, for iron ores; bituminous stone or inflammable gas, for pit-coal; the frequent occurrence of fragments of particular ores, etc.; or, in the geological epoch and nature of the rocks. Marks of this kind acquire new importance, when, in a district susceptible of including deposites of workable ores, the vein-stones are met with which usually accompany any particular metal. The general aspect of mountains, whose flanks present gentle and continuous slopes, the frequency of sterile veins, the presence of metalliferous sands, the neighborhood of some known locality of an ore, as ironstone, in reference to coal; lastly the existence of salt springs and mineral waters, may furnish indications.

Classification of Rocks.—To understand the relation which geology bears to mining, and the way in which it can be made subservient to its promotion, it is necessary to glance at some of the revelations which the science has made in regard to the structure and present condition of our globe, and the order in which the materials are arranged.

When a rock is divided into layers by seams, it is said to be stratified or divided into strata—each of these layers is called a stratum. When one mass of rock is contained in another, it is said to be imbedded or to occur in a bed. The inclination or general direction of the strata is called the dip. This is an important point to ascertain. Formation is used to signify a mass of mineral substances formed by the same agent, under the same circumstances, and at the same time.

Suppose ourselves to have arrived upon a large and extensive plain, which skirts the base of an elevated mountainous district, and begin a perpendicular excavation into the earth, we shall pass through the different classes of rocks in the following order:

For nearly one hundred feet we shall pass through layers of loam, clay, sand, and fine gravel. This deposite, from an existing river, is denominated *alluvium*. which is the soil and earth which rests upon the rocks. Having penetrated this, we shall find ourselves upon the second formation, called drift or *diluvium*. This is composed of coarse sand or gravel, with fine sand, containing large rounded masses of rock called boulders. The third series of strata which we shall penetrate, is composed of layers of clay, sand, gravel, and marl, with occasional beds of quartz and limestone. They contain many petrifactions, and are usually horizontal. They are called *tertiary*. After passing through these, we come to the secondary, composed for the most part of solid rock, mostly made up of sand, clay, and pebbles, cemented together. With these we find many remains of animals and plants, graywacke, limestone, sandstone, coal, lias, clay, marl, green sand and chalk. Below this are the primary rocks. They are destitute of organic remains, have a structure always crystalline, and are more highly inclined. Here occur granite, gneiss, mica slate, limestone, gypsum, talcose slate, hornblende slate, quartz rocks, and clay slate.

Veins.—These are seams, or tabular-shaped masses, that almost always traverse the direction of the strata, and are composed of materials that differ from those of the rocks which they intersect. They vary much in their magnitude, yet the length and depth always bear a certain proportion to each other, and the breadth to the length and depth. The length and depth are frequently nearly alike. Few metalliferous veins reach above 1800 feet in depth, or 1200 feet below the surface of the mountains in which they are situated. In general, veins continue in one direction, and are usually much inclined, always more so than beds. The metallic matter called ore rarely occupies the whole of the vein, but is disseminated through the quartz, sulphate of baryta, wacke, granite, etc., which constitutes the greater part of the vein, and is called the gangue, matrix, or veinstone.

Metallic veins are most numerous in primary and secondary rocks. They occur more frequently in flat hilly country than in steep mountainous country, and generally on the ridges of the hills. Beds, on the contrary, are more abundant in steep and mountainous country. As a general fact the veins are seldom rich near the surface; but increase in value at a medium depth, and grow poor again at a greater. They are most productive near the junction of stratified and unstratified rocks. Their productiveness also depends on their direction somewhat; an east and west direction being regarded in some mines as the most favorable, while the north and south veins are usually unproductive. Great metalliferous veins usually run parallel with the general direction of great valleys.

Of the Instruments and Processes of Subterranean Operations.—It is by the aid of geometry, in the first place, that the miner studies the situation of the mineral deposits, on the surface and in the interior of the ground, determines the several relations of the veins and rocks, and becomes capable of directing the perforations toward a suitable end. The instruments are: 1. The magnetic compass, which is employed to measure the direction of a metallic ore, wherever the neighborhood of iron does not interfere with its functions. 2. The graduated semi-circle or clinometer, which serves to measure the inclination. 3. The cord or chain, for measuring the distance of one point from another. 4. When the neighborhood of iron renders the compass uncertain, a plane table or plate is employed.

Means of Penetrating into the Interior of the Earth.—1. Manual tools; 2. Gunpowder; and 3. Fire. The pick is a light tool used for digging or removing in small quantities. The side is used as a hammer; the point is of steel, carefully tempered. The gad is a punch or wedge of steel, with a wooden handle, driven into small openings of rocks. The shovel has a pointed form, to enable it to penetrate among the coarse and hard fragments of the mine rubbish. The blasting or shooting tools are, a sledge, borer, claying-bar, needle or nail, scraper, tamping-bar. The borer is an iron bar, tipped with steel, formed like a thick chisel. A hole being bored, a cartridge is inclosed in it, furnished with a stem or tube, through which the powder may be ignited. Any soft species of rock, free from flinty particles, is used for cramming the whole, and is rammed by the tamping-bar. Each hole bored in a mine should be so placed, in reference to the schistose structure of the rock,and to its natural fissures, as to attack and blow up the least-resisting masses. The quantity of gunpowder should be merely sufficient to split it. In certain rocks and ores of extreme hardness, the action of fire is used with advantage, to diminish the cohesion of the rock.

When the existence of a deposite of ore is merely suspected, without positive proofs, recourse must be had to labors of research; in order to ascertain the richness, nature and disposition of a supposed mine. Subterranean workings afford the most satisfactory knowledge. They are executed, 1. By longitudinal galleries, hollowed out of the mass of the beds or veins themselves, in following their course; 2. By transverse galleries, pushed at right angles to the direction of the veins; 3. By inclined shafts, which pursue the slope of the deposites and are excavated in their mass; 4. By perpendicular pits

If a vein or bed unveils itself on the flank of a mountain, it may be explored, according to the greater or less slope of its inclination, either by a longitudinal gallery, opened in its mass from the outcropping surface, or by a transverse gallery falling upon it in a certain point, from which either an oblong gallery or a sloping shaft may be opened.

Metallic ores occur in four modes: 1. In regular, interstratified layers or beds. 2. In veins or fissures crossing the strata, and filled with the ore, united with some matrix. 3. In irregular masses. 4. Disseminated in small fragments through the rocks.

METALS—Their Chemistry and Geology.

General Properties.—A metal is a body which conducts electricity and heat, which is opaque, and has a high and peculiar brilliancy, known as the metallic luster.

Extraction.—Metals are seldom found naturally in their metallic form. When they so occur they are said to be in a native state. Their characters are generally masked under some form of combination with oxygen or sulphur, and are then said to be in the state of ore. They are met with, genrally, in veins penetrating the strata, intermixed with various earthy substances. To separate the metal, after it is dug from the mine, the mass is broken up, and subjected to the operations of sorting, stamping, washing, roasting, smelting, and refining. Under each metal will be included the method of reducing its ores.

Assaying.—This is the determination of the quantity of any particular ore, to discover whether it will be worth while to extract it largely, and in what manner the process is to be conducted. The knowledge requisite for this is called the docimastic art.

GOLD.

1.—Gold.—*Geognostic Situation.*—This metal has hitherto been found only in the metallic state, either pure or in combination with other metals. It occurs in veins, and disseminated in primary and secondary rocks, and abundantly in alluvium or drift, which constitutes certain plains, and margins of rivers. The rocks in which it most often occurs are granite, quartz, slate, hornstone, sandstone, limestone, gneiss, mica-slate, and especially in talcose slate, and rarely in graywacke and tertiary strata, but never in serpentine.

It also occurs in veins of iron ore, antimony, zinc, lead, barytes, etc. When the metal exists in the bosom of primary rocks, it is particularly in schists. The gold of commerce is almost exclusively foupd in alluvial deposites, where it occurs in small particles or grains,called gold dust, mingled with sand and debris. It sometimes occurs in beds or layers, instead of veins, which conform to the regular structure of the slaty rocks. It is usually found alloyed with small portions of other metals, particularly silver and copper.

Extraction.—When native gold is found in a state of mixture with foreign matters, its extraction is commonly performed by amalgamation with quicksilver. The whole of the matter procured from the vein is collected and broken into pieces, about the size of a nut, which are arranged into heaps according to their richness. The quantities thus procured are afterwards freed from most of the stony matter mixed with it, by pounding and washing. They are then reduced to powder, and made into a thick paste with salt and water. Quicksilver is now squeezed through a leathern bag on the mixture, and as the metal flows in in minute globules, it is intimately blended with it by means of wooden spatulas. When the requisite quantity of mercury is added, the whole is beaten together, and kept for two or three days about the temperature of boiling water, by which means the union of the metals is promoted. The earthy matter is then carried off by washing or levigation, and most of the mercury removed by squeezing the remainder through a leather bag. The residue is subjected to distillation or heat only, by which the mercury is expelled and the gold obtained, alloyed perhaps, with a little silver. When the gold is contained in other ores, the metallic are first separated from the earthy substances. For doing this, the ore is reduced to a powder in stamping mills. This mill consists of a cistern through which water flows, and heavy beams of wood terminated below by iron, and moved upwards and downwards. The powder is carried off by the stream into vessels, where it is deposited; the heaviest being deposited nearest the cistern.

The vessels are of different sizes ; that nearest the cistern being about twelve feet long and nine inches in breadth, and as many deep. The others gradually enlarge as they retire. They also vary in their inclination, the first having a slope of about three inches, the second about one inch, the third and fourth about half an inch, and the fifth and sixth being level. Each vessel is furnished with a groove at the extremity farthest from the cistern, into which pieces of wood are placed, varying in hight according to the quantity of ore collected in the vessel, and each vessel communicates with that beyond it. When the water flows from the mill into the first vessel, the heavy part of the ore is deposited and collected where the wood is put into the groove ; as the powder reaches the top of this another piece is put over the former, and so on till the vessel is nearly filled ; then the water is allowed to flow into the second vessel, and from this, when full, into the third. The particles of ore thus procured are still farther freed from impurities by washing. Each parcel is put into a wicker basket, into which a stream of water flows, and is received on inclined tables, grooved in various directions. If the gold thus procured is mixed only with earthy matter, it is triturated with quicksilver, as before described, or fused in crucibles with some flux, as nitre or pearlash. If, however, it contains inflammable matter, as sulphur, it is roasted. Lime and lead ore are mixed with it in quantity proportionate to the gold, and kept at a red heat till part of the sulphur is driven off. Increase the heat until the whole melts, after which pour it into molds of sand. By repeated fusions, the gold is obtained alloyed only with silver, copper and lead, from which it is freed by refining or cupellation.

The impure gold is melted with two or three times its weight of lead, and exposed to heat on a cupel under a muffle or on a hearth of a refining surface. When the greater part of the foreign metals is abstracted, the remaining fused metal will, if the process is completed, exhibit various colors, and at length suddenly brighten, and its surface become highly luminous. The metal is detached while hot. The gold, even after this process, may be alloyed with a little silver; it is therefore subjected to the operation of parting. The principal agents employed in this process are nitric acid, marine acid, and sulphur. Parting by the first is the most convenient and most used. It is called simply parting. That made by marine acid is by cementation, and is called centrated parting. Parting by sulphur is made by fusion, and is called dry parting.

Parting by Nitric Acid.—The first step employed is quartation, which consists in fusing three parts of silver with one of the gold; for to ensure success, the silver must be to the gold as three to one. The alloy must next be granulated by melting it in a crucible, pouring it into cold water and stirring it briskly. It is then put into vessels of a pear-shape, about twelve inches long and seven wide at the bottom, with twice its weight of nitric acid (aquafortis). The vessels are then gently heated on a sand-bath, and when the action has ceased, the liquor is to be poured off and more acid added. The gold left is washed with tepid water, until the liquor which comes off does not stain a piece of copper. It is then fused in a crucible with borax and niter. The silver in the liquor may be recovered by putting in a piece of pure copper.

Centrated Parting or Cementation.—The alloy is first beaten into thin plates, and placed in alternate layers in a pot, with a cement composed of four parts of bricks powdered and sifted; of one part of copperas calcined till it becomes red; and of one part of common salt: this is made into a thick paste with a little water. The whole is covered with a lid and luted, and then exposed to heat, until a great part of the alloying metals are removed. This will take twenty-four hours, but the heat must not be raised so as to melt the gold. If it is not sufficiently pure, it is cemented a second time. This process is chiefly used to extract silver from the surface of gold.

Dry Parting or Fusion.—The alloy is first melted and granulated. About seven-eighths of it are then mixed with about one eighth of the flowers of sulphur, and the mixture heated in a covered crucible, first slowly, and afterwards till the whole is brought into fusion, in which state it is kept on the fire for an hour; one-third of the alloy reserved is then added and thoroughly stirred with it by means of a wooden rod, and the whole is again heated for about an hour. Another third of the alloy is then mixed with it, and after a similar operation the remainder is added, and the mixture kept fused for three hours, during which it is frequently stirred. When the surface has become quite white, it is then poured into greased cones. When cold, the upper part will be found to be sulphuret of silver, and the lower a metallic button composed of gold and silver. If the former contains gold, it must be heated in an open crucible. The metal is repeatedly subjected to the same process; and the gold is thus concentrated into a smaller part, so that it may be parted by aquafortis without too much expense.

When the gold is found mixed with sand or gravel only, it may be separated by washing; a process in which advantage is taken of the difference of specific gravity. It is sometimes performed by hand, in wooden vessels or troughs, which cross a current of water; and sometimes, if the ore is rich and valuable, upon inclined tables, covered with cloth. The metal sinks first, while the stony matter, which is lighter, is carried farther down the current. A decided improvement on this has been made by a European, and patented in 1844. In this process the gold, with its impurities, is subjected to the combined action of two currents of water—one vertical and the other horizontal; the former carrying the impurities above the level of the metallic particles, and the latter washing them away. The apparatus consists of a series of sieves separated by partitions, and surrounded by a casing with a valve opening upwards, and placed at one end of the series. The materials are dropped into the first sieve of the series from the hopper above, adapted to the delivery in given quantities, and the sieves then receive a vertical reciprocating movement in a water tank. On the descent of the sieves, the water passes through the meshes of the sieve and the valve; the former producing the vertical current, loosening the lighter and impure particles, and carrying them above the partitions; and the latter, the horizontal current, washing all that has been carried above the partitions to the next sieve, and so on to the end of the series, to catch the particles of gold that may have been carried up with the impurities.

Assaying.—Reduce the ore to powder, mix it with four parts, by weight, of dry caustic potash and one of fused borax, and subject it to heat in a silver crucible. When fused, pour it out, and if any remains in the vessel, remove it by muriatic acid. Digest this with the fused matter reduced to powder in muriatic acid, to which from time to time add a little nitric acid. When the action ceases, pour off the solution, and wash well with water the residue, the washings being mixed with the solution. To the solution add copperas until no precipitate falls, wash the precipitate and fuse it in a crucible with half its weight of niter and a little borax, when a button of pure gold will be found at the bottom.

Iron pyrites containing gold is analyzed by digesting the ore in muriatic acid, with the addition of a little aquafortis. What is left is roasted to drive off the sulphur, and again digested in acid. The solutions obtained must be neutralized by potash, and proto-nitrate of mercury is added. The precipitate thrown down is then fused with niter, by which the gold is procured. If there be silver in the ore, it is obtained by treating that part of it not acted upon by the acid with caustic, potash and muriatic acid. Lead ore containing gold is analyzed by digesting it in aqua regia, evaporating the solution, and then adding proto-nitrate of mercury. The part insoluble, when treated as above, will yield the silver in a pure state.

The assay of the alloys of gold will be treated under article *Silver.*

The process of assaying in the dry way consists in melting the gold with lead in a cupel, when the lead, combining with the other metals the gold contained, sinks into the substance of the cupel, leaving the gold on the surface. Gold dust is thus assayed.

External Characters.—Color, golden or orange yellow, passing into grayish yellow; in some varieties inclines to brass-yellow. Seldom occurs massive, often disseminated, capillary, amorphous dentritic, and crystallized in cubes, octohedrons, rhomboidal dodecahedrons, and tetrahedrons. Internally, shining, glistening and metallic. Fracture, hackly. Tessular. No cleavage. Soft, malleable, ductile, tenacious. Specific gravity = 19·26 to 19.5.

Chemical Characters.—Unaltered by exposure to air, moisture or acids. Soluble in aqua regia. Fusible with the blow-pipe. Melts at 2016° Fahrenheit.

Distinctive Characters.—Gold is the only metal which has a yellow color. Its malleability will distinguish it from iron and copper pyrites, and from yellow mica, for each of which it is often foolishly mistaken.

The gold of Africa is often adulterated with these pyrites and brass-filings. This fraud may easily be detected by throwing the dust into aquafortis, which dissolves the substances and leaves the gold untouched.

PLATINUM.

2.—PLATINUM.—*Geognostic Situation.*—This metal occurs only in the metallic state, associated or combined with various metals, as copper, iron, lead, gold, silver. It is frequently disseminated in rocks of igneous origin, as the primary. It is often found in sienite, associated with gold. But it occurs principally in alluvium or drift.

Extraction.—The grains must be first spread on a table, and a current of air from a bellows passed obliquely over them. By this the lighter particles, as quartz and iron ore, are removed. The crude metal is then dissolved in aqua regia, and a solution of sal-ammoniac added. The precipitate is then exposed to heat. The fine powder thus obtained is subjected to violent pressure in a brass tube. It is then heated to the highest temperature of a smith's forge, and carefully hammered. After this operation it is coated with a reddish crust, which is removed by covering it with borax and exposing it to a white heat; it is then washed with muriatic acid, which leaves the metal resplendent.

Sometimes the grains contain a little gold. This may be separated by dissolving them in aqua regia. To the solution add copperas, and fuse the precipitate with niter and borax.

Assaying.—Digest in a retort one hundred grains with ten times its weight of aqua regia; apply the heat of a lamp till half of the acid passes over into the receiver; decant the fluid remaining, and repeat the process with acid. Filter. To the solution add a solution of sal-ammoniac; wash and dry the precipitate. Heat in a crucible until all fumes cease. The weight of the spongy mass will show the per centage of the metal.

External Characters.—Color, very light steel-gray, approaching to silver-white. Occurs in grains and rolled pieces, seldom larger than a pea, and resembling coarse iron filings. Roundish. Shining and glistening. Streak unchanged. Hardness nearly equal to that of iron. Malleable; ductile. Structure sometimes lamellar, but often not obvious. Specific gravity, = 20.98.

Chemical Characters.—Infusible in the hottest furnaces, but melts before the compound blow-pipe. Unaltered by exposure to air, moisture or acids. Dissolves in aqua regia.

SILVER.

3.—SILVER.—*Geognostic Situation.*—This metal is found mostly in primary and secondary slates. It is found native, also combined with sulphur and muriatic acid. It likewise occurs in the metallic state, mixed with copper, antimony, lead, arsenic, gold. The rocks richest in it are gneiss, mica-slate, clay-slate, graywacke.

Extraction.—Silver is extracted from its ores by amalgamation and fusion. The first process is followed when the ore is rich in silver, the latter when it contains little.

Amalgamation.—The ore, being freed as much as possible from its stony ingredients, is mixed with common salt, in the proportion of nine to ten per cent. It is then exposed for some hours on the floor of a reverberatory, till the vapor ceases to come off; the mixture being frequently stirred. When the matter is cold it is reduced to powder in a mill, and mixed with an equal quantity of quicksilver. The amalgamation may be performed in barrels, which are made to revolve. The mixture being put into these vessels it is made into a thick paste with water, and kept agitated for about forty-eight hours; and when the amalgam has fallen to the bottom, it is withdrawn through an aperture. The remainder is then washed to get more of the amalgam, and the residual matter roasted with about three per cent of sulphur, and subjected to a similar process. The amalgam is squeezed in a leather bag to remove the superfluous mercury, and then subjected to distillation.

Fusion.—The ore generally subjected to this process is lead glance. It is first subjected to stamping and washing, then roasted in a reverberatory, the heat not being raised so much as to melt it; and when it begins to adhere together on its surface it must be well stirred. In five or six hours, the flame changes from blue to white; charcoal in powder is then thrown in, by which part of the lead collects at the bottom. When enough is formed, quicksilver is mixed with the scoria to thicken it, and the fused metal is drawn off. After this the heat is continued, and the metal is taken out as it is formed, the temperature being increased. The metal as it is collected is covered with charcoal, and the scoria removed. It is then covered with sawdust, pieces of wood, and a little resin, and constantly stirred. When the flame ceases it is poured into moulds. It is then subjected to cupellation, as described under article *Gold*.

When the ore contains copper, it is mixed with another ore containing silver, iron, and sulphur, and with the scoria of a former process. The mixture is fused in a blast furnace. The matter, during cooling, separates; that below is roasted to expel the sulphur and arsenic, and to rust the iron. It is then mixed with one and a half of rich ore and some scoria, and is fused. The metallic matter obtained is again roasted, and fused with about one half of litharge and as much scoria. When cold it separates into three parts; the second, containing copper and silver, is melted with lead and copper scoria, afterwards with litharge and scoria. If it is not pure, then it must be repeatedly fused.

Assaying.—The method of examining the purity of silver is by mixing with lead, and is the same as cupellation. The ore must first be roasted, and then mixed with litharge and quickly fused. The product is then fused with black flux; the metallic button which falls is mixed with the proper quantity of lead and placed in the cupel.

Assay of Gold Alloyed with Silver.—The alloy being mixed with the due proportions of lead and silver (the latter amounting to three times the quantity of gold) is placed in a muffle, and the cupellation performed as above. When the process is finished the button of metal is taken out, and kept in a state of fusion in a crucible for some time, by which the lead is expelled. When cold, it is beaten into a plate, again made red-hot, and slowly cooled. It is afterwards extended into a thin leaf between steel rollers, and coiled loosely up, in which state it is submitted to the process of parting, described above. The quantity of lead added to the alloy should be forty parts to three of silver. In the cupellation there is little risk of making the heat too high.

The best mode of separating copper and silver is to throw the article in a glazed earthenware dish, in which one pound of niter is dissolved in nine pounds of oil of vitriol, with the aid of a little heat. The heat is then raised to about 200°. When the silver is dissolved the fluid is poured off, and the metal is precipitated by common salt, and obtained in the usual way, or the solution is diluted with water, and pieces of pure copper are immersed in it.

The forms in which silver occurs in nature are:

Native Silver.

Geognostic Situation.—Primitive and secondary rocks with the ores of silver, copper, cobalt, etc. It often occurs penetrating crystals, or amorphous pieces of common quartz.

External Characters.—Color, silver white, often tarnished gray, or reddish. Occurs dentiform, capillary, ramose, reticulated, seldom massive, more frequently disseminated; also in plates and spangles, and crystalized in tubes, octohedrons, rhomboidal docahedrons and tetrahedrons. Luster, splendent to glimmering. Fracture, fine hackly. Specific gravity = 10 to 10·5.

Chemical Charac[illegible]—Fusible into a globule. Melts at 1873° or a red heat. Soluble in aquafortis, forming the well known lunar caustic.

Distinctive Characters.—Its color and malleability.

Composition.—Silver, with a little iron, antimony, copper or arsenic.

Antimonial Silver.

Geognostic Situation.—In primary rocks, as granite and clay-slate, associated with the other ores of silver.

External Characters.—Color, silver or tin white. Occurs massive, in grains and in cylinders, also in curved laminæ. Yields to the knife. Fracture, conchoidal. Specific gravity = 9 to 10.

Chemical Characters.—Fusible, with the emission of antimonial vapor, into a globule of silver.

Distinctive Characters.—Want of ductility; and the antimonial vapor; not giving a blue globule with borax.

Composition.—Silver 84; antimony 14.

Sulphuret of Silver.

Geognostic Situation.—Primary and secondary rocks, associated with the other ores of silver. It is an important ore for the extraction of the noble metal.

External Characters.—Color, dark, lead-gray, often with an iridiscent tarnish. Occurs in tubes and octohedrons;

also reticulated, ramose, lamelliform, amorphous, and in plates. Cleavage, imperfect. Fracture, flat, conchoidal. Malleable. Easily sectile Specific gravity = 7.

Chemical Characters.—Fusible with intumescence and odor of sulphur, leaving a globule of silver.

Distinctive Characters.—It may be distinguished from native silver by its less specific gravity, and its sulphurous odor under the blowpipe.

Composition.—Silver 85 ; sulphur 15.

Brittle Sulphuret of Silver.

Geognostic Situation.—Primary rocks, with the other ores of silver. It is a very rich ore.

External Characters.—Color, dark, lead-gray, or bluish gray, passing into iron black. Occurs massive and disseminated ; also in hexahedral prisms. Luster, metallic or dull. Structure, foliated ; crystals mostly intercept each other. Soft and brittle. Fracture, conchoidal. Specific gravity = 7.

Chemical Characters.—Fusible, with the evaporation of sulphur, arsenic and antimony, into a globule of silver surrounded by a slag. Soluble in aquafortis.

Distinctive Characters.—It differs from sulphuret of silver in its want of malleability, and from other ores by its dark color and brittleness.

Composition.—Silver 66.5 ; antimony 10 ; iron 5 ; sulphur 12 ; arsenic and sulphur 5.

Sulphureted Antimonial Silver. (Red Silver).

Geognostic Situation.—Primary rocks, chiefly in granite mica slate and porphyry. It is a valuable ore.

External Characters.—Color, red of various shades, passing into lead gray and grayish black ; powder, crimson red. Occurs in masses and grains, also dentritic, membranous, capillary and crystallized in hexahedral prisms, terminated by hexahedral prisms ; also, in double six-sided pyramids. Luster, metallic adamantine ; crystals often striated. Structure, imperfectly foliated. Yields to the knife. Translucent, opaque. Specific gravity = 5·20 to 6·68.

Chemical Characters:—Fusible, with antimonial fumes.

Distinctive Characters.—It differs from sulphuret of arsenic in having a greater specific gravity, and in leaving a globule of silver. Sulphuret of mercury is entirely dissipated by the blow pipe. The sulphuret of silver is malleable. Specular oxide of iron is magnetic after being submitted to the blowpipe, and the red oxide of copper is readily reduced to the metallic state by the blowpipe.

Composition.—Silver 60; antimony, 20·3; sulphur, 14·7; oxygen, 5.

Muriate of Silver. (Horn Silver).

Geognostic Situation.—Primary rocks, with the other ores It is a good ore for the extraction of the precious metal.

External Characters.—Color, pearl gray, greenish or reddish blue, yellowish or greenish white and brown. Occurs massive, investing other minerals, reniform, amorphous, and crystallized in tubes, octohedrons and acicular prisms. Luster, glistening and wavy. Soft, yields to the knife, and to pressure. Malleable. Feebly translucent. Becomes brown by exposure. Specific gravity = 5·5.

Chemical Characters.—Fusible in the flame of a candle. Before the blowpipe emits muriatic acid fumes. Rubbed on moistened zinc it leaves a film of silver.

Distinctive Characters.—Muriate of mercury is entirely volatile before the blowpipe, and does not leave a silver globule.

Composition.—Muriate of silver 88·7; oxide of iron, 6; alumine, 1·75; sulphuric acid (oil of vitriol) 0·25.

Tests for Silver.—Dissolve the metal in nitricacid, put in a quantity of potash or soda, and it will give a dark olive precipitate; put in a piece of copper, metallic silver will fall down; common salt gives a white precipitate, and galls a brown precipitate. Its solution is called indelible ink.

MERCURY.

4.—**Mercury.**—This metal is sometimes found in the native state, but the ore or source whence the greater portion is obtained is the

Sulphuret of Mercury. (Cinnabar).

Geognostic Situation.—Occurs chiefly in new red sandstone; sometimes in a sort of mica slate, limestone, gneiss, graywacke, beds of bituminous shale, associated with black mineral resin, gray sandstone and limestone, clay, alluvium, and in rocks of the coal formation.

Extraction.—Mix the ore with its weight of lime or clean iron filings, and put into iron retorts; and after a receiver containing some water is luted on, set them on sand-baths, and give them a sufficient degree of heat to force the mercury over.

Assaying.—Same as Extraction, which see. By this process one hundred pounds of ore yield from six to ten ounces of mercury.

External Characters.—Color, scarlet or carmine, passing into cochineal red and lead gray; sometimes with a tinge of yellow. Occurs massive, and crystallized in acute rhomboids; some varieties have a fibrous structure. Translucent or opaque. Streak, scarlet red. Luster, adamantine, inclining to metallic; sometimes shining silky. Fracture, granular or fibrous. Sometimes occurs in thin plates or tabular crystals. Specific gravity = 8.

Chemical Characters.—Volatile before the blowpipe, with the odor of sulphur.

Distinctive Characters.—From sulphuret of arsenic, red silver ore, arseniate of cobalt, and red oxide of copper, it is distinguished by its chemical character.

Composition.—Mercury 84.5; sulphur 14.75.

Tests for Mercury.—To a quantity of mercury dissolved in aquafortis, add fresh lime-water, result = an orange precipitate; immerse a piece of copper, result = metallic mercury; immerse a plate of iron, result = a dark powder.

COPPER.

5.—Copper.—Geognostic Situation.—Occurs in beds, imbedded in various primary rocks, and as high in the secondary series as the new red sandstone; also in large blocks in alluvial districts; very rarely in tertiary rocks.

Extraction.—The oxides and carbonates of this metal are reduced by simply heating them with charcoal in a wind furnace; but the sulphurets are reduced by a different and more difficult process. The ore is broken to pieces, and roasted to pieces in a furnace similar to a reverberatory, having a long chimney to increase the heat and to carry off the sulphur and arsenic. The roasting takes about twelve hours, the ore being frequently stirred. It is then put into a smaller furnace, and brought to a state of fusion, occasionally mixing it with a little lime. The impurities which collect at the top are raked out. The melted metal is drawn out through a hole in the lower part of the furnace, which was stopped by clay mixed with a little coal. The copper is conveyed into vessels suspended in a well; through which a stream of water runs. The metal being now in a granular state is repeatedly subjected to heat in a reverberatory, and each time put into the well. The slag which collects must be removed. The copper after this is kept at a low red heat for two days, then repeatedly fused, and cast into moulds. Lastly, it is put into the refining furnace with a little charcoal, in which it is again fused and cast. The purest part of it rises to the top, and may be separated by a blow of a hammer.

Copper is obtained from the springs which contain this metal, by putting in pieces of iron. The matter deposited is then fused.

Assaying.—The ores must in the first place be roasted with a gentle heat. After this, it is to be pulverized and mixed with twice its weight of black flux in a crucible, and exposed to a strong heat of a smith's forge for about half an hour. Should the globules of revived metal not readily form a button at the bottom, a little salt thrown in will accomplish it.

The ores of copper present the following varieties :

Native Copper.

Geognostic Situation.—In the veins of primary and secondary rocks.

External Characters.—Color, copper red, tarnished externally, brownish black. Occurs dentritic, capillary, reniform and amorphous; also crystallized in cubes and octohedrons. Malleable. Specific gravity = 8.5.

Chemical Characters.—Fusible. Soluble in acids.

Composition.—Nearly pure copper.

Sulphuret of Copper.

Geognostic Situation.—Found in almost every kind of repository in all the great classes of rocks; particularly in beds and veins in primary and secondary rocks. It is a valuable ore.

External Characters.—Color, blackish steel-gray, sometimes iridiscent; internally lead-gray. Occurs massive, and in pseudomorphous crystals; also crystallized in long tabular six-sided prisms, and in double six-sided pyramids. Structure lamellar. Tessular. Cleavage easy with brilliant faces. Easily broken into grains. Fracture conchoidal. Specific gravity = 5.

Chemical Characters.—Soluble in hot aquafortis. Fusible.

Distinctive Characters.—Gray copper decrepitates under the blowpipe and is harder. This gives out only the fumes of sulphur.

Composition.—Copper 76·50; sulphur 22; iron 0·50.

Copper Pyrites.

Geognostic Situation.—Same as that of the preceding. It is one of the most abundant and valuable ores of copper.

External Characters.—Color, brass-yellow. Occurs dentritic, stalactical, amorphous, in concretions, and crystallized in tetrahedrons and dodecahedrons. Luster, metalic. Struc ture, lamellar. Crystals, small and seldom perfect. Cleavage, tessular. Yields to the knife. Fracture, commonly uneven. Specific gravity = 4·3.

Chemical Characters.—Fusible. Tinges borax green.

Distinctive Characters.—Iron pyrites does not tinge borax green. Native bismuth is lamellated, and native gold is malleable.

Composition.—Copper 40. to 35·3; iron 40. to 33; sulphur 20· to 35.

Gray Copper.

Geognostic Situation.—Accompanies the other ores of copper.

External Characters.—Color, steel-gray, passing into black Streak, brownish. Occurs amorphous, disseminated, and crystallized in tetrahedrons. Luster, metallic; brittle. Crystals small. Specific gravity = 5.

Chemical Characters.—Fusible, but not easily reduced.

Distinctive Characters,—Specular oxide of iron is magnetic; arsenical iron is harder, and gives out the fumes of arsenic when heated.

Composition.—Copper 52; iron 23; sulphur 14.

Red Oxide of Copper.

Geognostic Situation.—Associated with the other copper ores.

External Characters.—Color, red. Occurs amorphous and crystallized in octohedrons and cubes. Structure, lamellar. Luster, metallic adamantine. Fracture, conchoidal and uneven. Translucent. Yields to the knife. Brittle. Specific gravity = 4 to 5·9.

Chemical Characters.—Fusible and easily reduced. Dissolves in aquafortis with effervescence; in muriatic acid, without.

Distinctive Characters.—Its chemical characters.

Composition.—Copper from 88·5 to 91; oxygen from 11·5 to 9.

Blue Carbonate of Copper.

Geognostic Situation.—In primary and secondary mountains.

External Characters.—Color, blue. Occurs massive, stalactical, incrusting, disseminated and crystallized. Fracture imperfectly foliated, usually presenting broad fibers.

Chemical Characters.—Infusible without a flux; with borax gives a green glass. Dissolves in aquafortis with effervescence.

Distinctive Characters.—Insoluble in water; does not become magnetic under the blowpipe.

Composition.—Oxide of copper, 70; carbonic acid 24; water 6.

Tests for Copper.—To a solution of this metal present a plate of iron, result = metallic copper; potash, result = green precipitate; ammonia (hartshorn) result = blue color.

Copper melts at 1996°; it is ductile, malleable and tenacious; it is hard, elastic and sonorous.

IRON.

Geognostic Situation.—It occurs in primary and secondary rocks.

Extraction.—The ore is first broken into small pieces by the aid of the stamping-mill. After this it is roasted with a strong heat. It is then transferred to the blast-furnace, in which the operation of smelting is conducted. This is a large pyramidal stack, made of brick or hewn stone, from twenty to sixty feet high, having the inside cavity shaped like an egg, with its large end downwards, and lined with fire-brick or stone. Into this is placed alternate layers of charcoal or coke, and of the metallic matter; a quantity of lime is at the same time added as a flux. Before putting these in, however, the furnace must be first heated with coal only for twenty-four hours, and is then charged with the ore, etc., until it is quite full; a strong heat is then excited by bellows. As fast as the materials sink, by the melted metal being drawn out, the charge is renewed at the upper part. The slag rises to the surface and is drawn off by an opening while the metal collects at the bottom. The latter is drawn off at intervals, and cast into moulds, and is then known as pig iron or crude iron. To obtain it still purer, it is broken in pieces and kept in fusion in a puddling furnace, where it is raised to a very high temperature, and frequently stirred with an iron rod. At length the mass swells, emits a blue flame, and gradually becomes stiff and pasty. It is finally raised in a rude ball, and placed under the blows of a large tilt-hammer. It is cut up and piled or fagoted, and reheated several times, until it is made into tough and fibrous metal. It thus becomes the malleable iron of commerce, under the name of wrought, forged, or bar iron.

Assaying.—The ore should first be roasted with a strong red heat, as long as any smell arises. After this, two parts of the mineral are to be intimately mixed by trituration with one of fluor spar, one of charcoal, and four of salt, by weight. If the ore contains much stony matter, one part of black flux must be added to the mixture. The whole is then put into a covered crucible, and exposed to a white heat for an hour; after which a button of cast iron will be found at the bottom which determines the percentage.

The ores from which the iron of commerce is extracted are:

Brown Hœmatite.

Geognostic Situation.—Occurs abundantly in primary districts, and sometimes in secondary. It yields the finest kind of iron.

External Characters.—Color, brown, yellowish, or blackish brown; on the outside resembling black glazed earthenware. Occurs stalactical, tuberous, nodular, and amorphous. Structure, fibrous. Lustre, silky and resinous; yields to the knife. In a variety of this ore the structure is compact; lustre, none; streak, yellowish brown; fracture, conchoidal or earthy.

Red Hœmatite.

Geognostic Situation.—Chiefly in the primary, often in lead mines. It yields the best of iron for drawing and rolling.

External Characters—Colors, blood-red and dark steel-gray. Occurs massive, and in plates ; also reniform, globular, and pulverulent. Fracture, uneven and earthy. Yields easily to the knife. Adheres to the tongue. Specific gravity 4.75.

Chemical Characters.—Infusible, but becomes magnetic.

Composition.—Oxide of iron 90 ; silex 2 ; lime 1 ; water three.

Specular Oxide of Iron. (Iron Glance.)

Geognostic Situation.—Occurs chiefly in primary mountains, associated with magnetic iron, red hæmetite, quartz, etc.; also in secondary rocks. Affords good malleable iron.

External Characters.—Color, steel-gray, with a highly polished surface ; often tarnished. Streak, cherry-red. Occurs crystallized in pyramidal dodecahedrons, hexahedral tables ; also massive, disseminated, in concretions. Structure, lamellar. Lustre, brilliant ; slightly attracted by the magnet. Specific gravity=5·52.

Chemical Characters:—Infusible. Insoluble in acids.

Distinctive Characters.—Yields a red powder when heated, and becomes magnetic.

Composition.—Iron 69 ; oxygen 31.

Magnetic Oxide of Iron. (Iron Sand.)

Geognostic Situation.—Occurs imbedded in trap rocks, and called mountain ore. Furnishes best bar iron, and yields from fifty to ninety per cent. of the metal.

External Characters.—Color, iron-black. Occurs in minute grains ; also in octahedral crystals. Fracture, conchoidal. Strongly magnetic. Powder, black.

Chemical Characters.—Infusible by blowpipe.

Composition.—Oxide of iron 85:50 ; oxide of titanium 14; oxide of manganese 0:50

Spathic Iron. (Clay Iron Ore).

Geognostic Situation.—It occurs in veins in granite, gneiss, mica-slate, clay-slate, and graywacke, and in these it is associated with ores of lead, cobalt, silver, but seldom with nickel and bismuth; more frequently with galena, copper ore, iron pyrites, and antimony ore. In other veins it is accompanied with brown, red, and black iron ore, calcareous spar, and quartz. But the most extensive formations of this ore are in carboniferous limestone, in which it is arranged in thick beds. It is also found filling up amygdaloidal cavities in trap rocks. It is excellently suited for steel-making; the black variety affording the best.

External Characters.—Colors, yellow, white, brown and black. Occurs massive, disseminated, with pyramidal impressions; also in granular distinct concretions—nodular; and crystallized. Structure foliated or lamellar. Lustre, shining vitreous. Streak, white or yellowish brown. Yields to the knife; easily broken. Crystals, usually small, and found in groups. Specific gravity = about 4.

Chemical Characters.—Infusible, blackens, and becomes magnetic. Effervesces with muriatic acid. Heated with borax, it makes an olive-green glass.

Distinctive Characters.—From the earthy minerals it is distinguished by its weight. From other iron ores, by crystalline, foliated cleavage; and from blende, by its yielding magnetic iron.

Composition.—Oxide of iron 58; carbonic acid 35; oxide of manganese 4.25; magnesia 0.75; lime 0.5.

Tests for Iron.—Infusion of galls, when added to iron dissolved in an acid, gives a black precipitate, (black ink); prussiate of potash gives a blue precipitate (blue ink).

LEAD.

The ore which is generally wrought, and from which nearly all the lead of commerce is procured, is the

Sulphuret of Lead. (Galena).

Geognostic Situation.—Occurs in veins, beds, and imbedded masses, in primary and secondary mountains, but most frequently in the latter, and particularly in limestone. It is commonly associated with the ores of zinc, copper and iron, and often with those of silver. When it is found in the primary rocks, it is generally in granite. It is also found in alluvial deposits.

Extraction.—The ore is first hand-dressed, then pounded and washed, to free it as much as possible of stony matter. What remains must be removed to a reverberatory furnace, where it is speedily made red hot. In this state it is frequently stirred, and when it begins to become soft, the heat is reduced until the whole of the sulphur is expelled. The fire is then made brisk, by which the lead is melted, and collects at the bottom. A little lime must then be thrown in, to thicken the scoria, and the lead is drawn off into moulds; the heat is again applied to the scoria, by which more lead is procured.

When the native salts are found with the galena, they are selected, roasted, and afterwards fused in contact with the fuel, with an addition of lime.

When silver is found in the lead in sufficient quantity to be worked, the latter is heated in a furnace; a current of air being directed on its surface, when melted by bellows. The silver is then freed from the small portion of lead left, by cupellation. Deducting the silver, the remainder is litharge.

Assaying.—Reduce a given weight of the ore to powder, place it on a muffle, and apply heat sufficient, so as on moving the muffle from the fire, the smell of arsenic and sulphur is no longer emitted. The roasting thus done, the ore is to be levigated—mixed with its own weight of black flux, and exposed in a crucible to a strong heat. The lead will be found at the bottom, which on being weighed and compared with the weight of the ore, will show the percentage.

In the roasting of lead ores, care must be taken not to fuse them.

External Characters.—Colors, bluish-gray, lead-gray, and on the outside, blackish-gray. Occurs amorphous, reticulated and crystallized in cubes and octohedrons. Structure, lamellated. Lustre, metallic. Perfectly sectile; soft. Very brittle. Opaque.

Chemical Characters.—When heated, first decrepitates, then emits the smell of sulphur, melting into a globule of lead.

Distinctive Characters.—Blende, molybdena, and graphite are infusible.

Composition.—Lead, sulphur, lime and silex.

Tests for Lead—Glauber's salts, and an infusion of galls, give to a solution of this metal a white precipitate.

TIN.

8.—Tin.—The only ore that is wrought to obtain this metal, is the

Oxyd of Tin. (Tinstone).

Geognostic Situation.—Occurs most commonly in primary rocks, where it is found in veins, traversing granite, gneiss, mica slate, clay slate, and porphyry, and is usually associated with chlorite, iron pyrites, topaz, quartz, fluor, etc. The metal extracted from the ore taken from this situation is called Block Tin. It is also found in alluvium and drift, and the ore is called Stream Tin, from which the metal being extracted, becomes the Grain Tin of commerce.

Extraction.—The ore which is procured from the mines is freed from impurities by stamping (see Gold), after which it is roasted in a reverberatory furnace, which is about seven feet long, five broad and fifteen inches deep. The usual charge of ore is seven cwt., which yields about two thirds of its weight in tin. The ore is again washed; it is then mixed with one-fifth of its bulk of coal and a portion of slacked lime, and smelted in the furnace for about six hours, at the end of which the metal collects at the bottom, covered with a black scoria. The tin is then drawn off into a shallow pit, in which it is freed from the scoria on its surface. It is then taken out with ladles, and poured into moulds. The metal is afterwards exposed to a gentle heat in a small reverberatory, by which the purest part melts first, and is conveyed off.

The stream tinstone is melted in a different way. The ore in its powdery state is submitted to a stream of water. It is afterwards bruised and passed through wire sieves. It is then blown, with alternate quantities of charcoal, into a blast furnace, in which, being reduced, it escapes through a channel at the bottom into pits; the scoria being removed as it collects, and thrown again into the furnace. The metal is then put into a large iron pot, where it is kept melted. In this state pieces of charcoal are thrown in. It is then tried, by removing a quantity in a ladle, and pouring it into the pot. If it appear bright, like silver, and of the same consistency throughout, it is pure. After this it is poured into moulds.

Assaying—Reduce the ore to a coarse powder, wash, and then expose to heat with charcoal until no garlic odor arises. What remains is to be mixed with half its weight of calcined borax or sawdust, and the same quantity of powdered pitch, and subjected to a strong heat in a crucible lined with charcoal. After the pitch is burnt, give a violent heat for a quarter of an hour, and on withdrawing the crucible, a button of pure tin will be found at the bottom, which shows the percentage.

External Characters.—Colors: brown, black, green, white, red, and yellow. Occurs in crystals, and in masses, from the size of grains to that of the fist. Luster, resinous or adamantine. Streak, grayish-white. Structure, lamellar. Gives sparks with steel. Brittle. Specific gravity = from 6·7 to 7.

Chemical Characters.—Decrepitates, but in powder may be reduced to metallic state on charcoal.

Distinctive Characters.—Spathic iron leaves a globule of iron under the blowpipe. Blende is infusible, and not so hard.

Composition.—Tin 77·5; oxygen 21·5; oxyd of iron 0·25; silex, 0·75.

Test for Tin.—To a solution holding the metal present a plate of iron, result = metallic tin.

ZINC.

9.—ZINC—Geognostic Situation.—Primary and secondary rocks.

Extraction.—The ore, being hand-dressed to free it from foreign matter, is roasted. The product is then washed, and the heavy part remaining is mixed with one eighth of its weight of charcoal. The mixture is next reduced to powder in a mill, in which state it is put into the pots to be smelted. These pots resemble oil-jars in shape. Through the bottom of each there passes a tube, the upper end of which terminates by an open mouth near the top of the pot; the lower end goes through the floor of the furnace into water. The pots are filled to the upper end of the tube with the mixture of ore and charcoal, and an intense heat is applied to them by a furnace. As the ore is reduced the zinc escapes in vapor through the tube into the water, where it is condensed in the form of globules. These are afterwards melted and cast into moulds. To make it still purer, it is again melted, and then well stirred along with sulphur and fat, the former of which combines with the foreign metals, and leaves the zinc nearly pure.

Assaying.—After being roasted, the ore is mixed with one-half its weight of charcoal dust, and exposed to a strong heat for one hour in an earthen retort, the mouth of which terminates in water. The metal condensed in the water and neck of the retort is collected and weighed.

The ores used in metallurgy are:

Blende. (Mock lead, False-galena, Black-jack):

Geognostic Situation;—Occurs in veins in primary and secondary rocks, generally associated with galena, with iron and copper. This ore is commonly too widely disseminated in its gangue to make it profitable. It is, however, used after roasting in the preparation of brass.

External Characters.—Colors, yellow, brown and black. Occurs massive, lamelliform, disseminated, in granular concretions, and crystallized. Luster, shining and adamantine. Yields to the knife. Brittle. Structure, foliated. Specific gravity = 3.7 to 4.

Chemical Characters.—When heated, decrepitates. When thrown into oil of vitriol it gives the smell of rotten eggs.

Distinctive Characters.—Infusible. Does not tinge borax green.

Composition—Zinc, sulphur, iron and silex.

Calamine.

Geognostic Situation—Occurs in beds, nests, filling up or lining hollows, in secondary limestone and conglomerate rock; also in veins, usually along with oxyd of iron, and sometimes with galena.

External Characters—Colors, gray, greenish, or brown yellowish; and sometimes nearly white. Occurs crystallized, compact, amorphous, pseudo-morphous and cupriferous. Yields to the knife. Specific gravity = 3.35 to 4.41.

Chemical Characters—Infusible. Dissolves with effervescence in muriatic acid or warm aquafortis.

Composition—Oxyd of zinc and carbonic acid.

Red Ore of Zinc.

Geological Situation—Iron mines; also in limestone.

External Characters—Color, red. Occurs massive and disseminated. Luster, shining, by exposure becomes dull. Structure, foliated. Yields to the knife. Brittle. Specific gravity = 6.22.

Chemical Characters—Infusible. Soluble with effervescence in acids.

Distinctive Characters—Infusibility and weight.

Composition—Oxyd of manganese and oxyd of zinc.

MANGANESE.

10—MANGANESE—This metal, in its metallic state, has not been converted into any use; but the ore, which answers, without preparation, all the purposes for which the metal is employed, is the

Black Oxyd of Manganese.

Geognostic Situation—Occurs in veins and imbedded masses in primary rocks; frequently found with the ores of iron.

External Characters—Color, very dark steel gray. Occurs massive, in fibrous concretions, and crystallized. Luster, metallic. Streak, black. Fracture, conchoidal and earthy.

Chemical Characters.—Infusible alone; but with borax forms a purple globule.

Composition—Manganese, oxygen and water.

COBALT.

11—COBALT—Cobalt is not procured in its metallic state for the purposes of art. The preparations of it in general use, are zaffree and smalt. The ore from which they are obtained is

Arsenical Cobalt.

Geognostic Situation.—Occurs in veins, traversing primary rocks, associated with nickel, bismuth, silver, arsenic and copper.

External Characters—Color, silver-white, with a tinge of copper-red. Occurs massive, dentritic, reticulated, stalactical, and crystallized in tubes and octahedrons. Luster, metallic. Brittle. Fracture, conchoidal. Yields with difficulty to the knife. Specific gravity = 6.33 to 7.30.

Chemical Characters—In the flame of a candle it emits the garlic odor and turns black. Melted with borax, gives a blue glass.

Composition—Cobalt, arsenic and sulphur.

To prepare Zaffree--Break the ore with hammers into pieces about the size of a hen's egg. Pound the mineral in stamping-mills and sift. Wash, and then put into a large flat-bottomed arched furnace, where the flame of the wood is made to play upon it. Stir often. The vapor is conveyed through a long flue, in which it is condensed. When the fumes cease, the ore is removed and reduced to powder, and again exposed to heat. It is then reduced to powder and sifted. This is the oxyd of cobalt. It is, however, commonly adulterated with three times its weight of powdered flints, moistened with water.

To prepare Smalt—Mix the pure zaffree with equal parts of potashes and sand. Heat it in large pots for ten or twelve hours, and frequently stir. Take it out in ladles and drop into water. Then pound, sift and grind.

NICKEL.

13—NICKEL.--The ore from which this metal is obtained is

Arsenical Nickel. (Kupfer or Copper Nickel).

Geognostic Situation—Accompanies cobalt. Secondary rocks.

Extraction—Roast well the ore. The greener the calx proves, the more it abounds in the metal. Fuse the roasted ore in an open crucible, with twice or thrice its weight of black flux, and the whole cover with salt. Expose it to the strongest heat of a forge fire, and the nickel will be obtained. It then generally contains a little arsenic and cobalt. To free it from the first, re-roast it; and from the second, by pouring ammonia into a saturated solution of the roasted ore in nitric acid. Filter, and the gray powder remaining is the nickel.

External Characters—Color, copper red. Tarnishes. Occurs massive, reticulated and botryoidal. Luster, metallic. Yields with difficulty to the knife. Specific gravity = 6·60 to 7.70.

Chemical Characters—Gives out garlic odor when heated Forms a green solution in aquafortis.

Composition—Nickel, arsenic, iron, lead, sulphur and cobalt.

BISMUTH.

13.—Bismuth.—Geognostic Situation.—Primary rocks and particularly in quartz, gneiss and mica slate, generally associated with cobalt, arsenic, silver, iron pyrites and galena,

Extraction.—When found native and alone, the metal is fit for use immediately.* Most of the bismuth used in the arts is obtained in the process for making smalt from the ores of cobalt. At the bottom of the crucibles the bismuth, with other metals, is found. Apply a gentle heat, and the bismuth, melting first, can be poured off.

External Characters—Color: silver-white, inclining to red. Occurs amorphous, plumose, reticulated and crystallized. Structure, lamellar. Luster, metallic. Softer than copper. Tarnishes. Melts at 476°. Specific gravity = 9.

ARSENIC.

14.—Arsenic.—Arsenic is not used in the metallic state in the arts; and no mines are wrought for obtaining it. The forms in which it is employed are:

Oxyd of Arsenic. (White Arsenic).

Geognostic Situation—This is a very rare mineral. It is found chiefly in the primary rocks, with the ores of cobalt, copper, lead, silver, etc.

Extraction—The white arsenic of commerce is procured by the process of roasting the ores of cobalt, nickel and iron. These are placed in large cast-iron boxes, to which horizontal flues are closely luted. These are heated by flues from a furnace. When red hot, about fifteen pounds of the ore are thrown in, and when all the arsenic has been driven off another portion of ore is put in, and the process continued for twelve hours, during which time about 150 pounds of the ore have been used. What is collected in the flues of the boxes is broken off by hammers, freed from any foreign matter adhering to it, and purified by a second sublimation.

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* Sometimes, however, it is necessary to mix it with half its weight of borax and of pounded glass, and subject to heat in a crucible lined with charcoal.

External Characters—Color: white. Occurs earthy, capillary, and investing; also crystallized. Luster, vitreous. Fracture conchoidal. Brittle. Specific gravity = 3·7.

Chemical Characters—At 380° it sublimes. Heated with charcoal, it gives a garlic odor. Soluble in ten parts of hot water. Poison.

Realgar.

Geognostic Situation—Occurs most frequently in veins in the primary rocks, less often in secondary; also among volcanic matter.

It may be formed artificially by heating white arsenic (ratsbane) with half its weight of sulphur, until the mixture is brought into a state of perfect fusion.

External Characters—Color, ruby-red. Occurs amorphous, disseminated, in flakes, in concretions, and crystalized. Luster, resinous. Streak, orange-yellow. Translucent. Soft; brittle. Becomes electric when rubbed on the sleeve. Specific gravity = 3.3 to 3·4.

Chemical Characters—Melts easily and burns with a blue flame and white smoke, emitting the smell of garlic and sulphur.

Distinctive Characters—The chromate of lead is much heavier, and tinges borax green. The red ores of silver and mercury are heavier and give a red streak.

Composition—Arsenic 69; sulphur, 31.

Orpiment.

Geognostic Situation--Secondary and primary rocks.

It may be prepared artificially by fusing together equal parts of white arsenic and sulphur.

External Characters—Color, lemon-yellow. Occurs reniform, disseminated and in plates. Luster, shining. Flexible. Translucent. Sectile. Specific gravity = 3·4 to 3·6.

Chemical Characters—Burns, emitting the smell of arsenic and sulphur. Becomes electric by friction.

Composition—Arsenic 57 ; sulphur 43.

ANTIMONY.

15.—ANTIMONY.—The ore from which the antimony of commerce is obtained is the

Sulphuret of Antimony.

Geognostic Situation—Primary and secondary rocks, chiefly in granite, gneiss and mica slate, associated with galena, blende, the ores of iron, copper and arsenic.

Extraction of the metal—The ore is broken, freed from stony matter, and then put on the hearth of a reverberatory furnace, and covered with charcoal. The metal is then melted, while the foreign ingredients float on the surface, and are removed by ladles. The metal is poured into moulds and forms crude antimony. From this the pure metal is obtained by scorification, For this purpose, eight parts of it are finely powdered, and mixed with six of crude tartar and three of nitre, and the mixture then thrown in successive portions into a red-hot pot. When the vessel is nearly filled, it is covered and a strong heat applied for half an hour ; the melted mass is then poured into a conical iron vessel, greased in the inside, in which it separates into different layers, the upper consisting of scoria, the lower of antimony in its metallic state.

External Characters of the Ore — Color : lead-gray. Streak, unchanged. Occurs massive, composed of delicate threads or needles, and crystallized. Luster, splendid. Fracture, fibrous. Yields to the knife ; brittle. Specific gravity = 4. to 4·80.

Chemical Characters—Melts in a candle-flame. Before the blowpipe emits the smell of sulphur and sublimes

Composition—Antimony 74 ; sulphur 26.

Anthracite. (Blind or Glance Coal.)

Geognostic Situation—Occurs in imbedded masses, beds and veins, in primary and secondary rocks, often in graywacke, sandstone, trap-rocks, slate, etc. It is also called stone-coal.

Black or Bituminous Coal.

Geognostic Situation—Chiefly in the secondary series, sometimes in clay, sandstone and limestone. Its varieties are called slate, foliated, cannel and coarse coal.

Lignite. (Brown Coal).

Geonostic Situation—Chiefly occurs in secondary rocks; also in alluvium. Its other names are, bituminous wood, earthy coal, alum earth, jet and moor coal.

Rock Salt.

Geognostic Situation—Secondary strata; often found associated with gypsum, clay, marl, etc.

Limestone.

Geognostic Situation.—Almost every rock below drift. The best marble occurs in the upper part of the primary, and lower part of the secondary rocks.

Gypsum.

Geognostic Situation.—New red sandstone, and other secondary rocks.

Clay.

Geognostic Situation—Secondary rocks. Porcelain clay is found in connection with granite.

Plumbago.

Geognostic Situation—In the coal formation; also in clay slate. It is often called graphite or black-lead.

Precious stones.

Geognostic Situation—Nearly all of them, as the sapphire, emerald, spinel, chrysoberyl, chrysoprase, topaz, iolite, garnet, tourmaline, chalcedony, amethyst, etc., are always in the primary rocks. Quartz in the form of rock crystal, carnelian cacholong, sardonyx, jasper, etc., is found often in secondary strata, especially in the trap rocks. The diamond is generally found in drift.

Improved System of Assaying.

ASSAY OF MINERALS CONTAINING GOLD.

Fusion.—In the assay of minerals containing gold, the object sought is to obtain that metal in the form of an alloy with lead, which is afterwards placed in a muffle, and cupelled, with various precautions. The mineral operated on is to be first finely pulverized in an iron mortar, and afterwards fused in an earthen crucible, with a certain proportion of litharge or red lead, and a sufficient quantity of powdered charcoal, to reduce to the metallic state a quantity of litharge varying with the nature of the ore treated, and the weight employed for each operation. The weight of litharge used must also itself be varied in accordance with the richness of the ore, and the nature of the gangue or matrix with which it is associated. If, which will frequently be the case, the substance operated on be either crushed gold quartz, or alluvial sands which have been more or less concentrated by washing, the following mixture will be found extremely convenient. For the sake of being more definite in the directions given, I will suppose the ore to be tolerably rich, and therefore four hundred grains will be a sufficient quantity to employ. If, however, poor ores are to be examined, double or even treble that quantity may be operated on, and in this case a proportionat quantity of flux must be used. In the case supposed where four hundred grains is the quantity treated, th resulting button of lead should at most not weigh abov two hundred grains, since, if the resulting button of alloy were too large, a greater length of time than convenient would be required for the cupellation. Neithe should it be too small; as in that case a part of th gold is liable to remain in the slags. In order then t obtain a satisfactory result, the four hundred grains o powdered ore must be intimately mixed on a sheet o highly glazed writing paper, with its own weight o litharge or red lead (dry white lead will do equally well when these are not to be obtained), two hundred grains of dry carbonate of soda, and from seven to eight grains of dry and very finely powdered charcoal. This mixture is introduced into an earthen crucible, of which it should not fill more than two-thirds the capacity. This is now covered with a thin layer of borax, and fused in an assay furnace, care being taken to withdraw the crucible from the fire as soon as a liquid and perfectly homogeneous slag has been obtained, since the unreduced litharge would otherwise be liable to cut through the pot, and spoil the experiment.

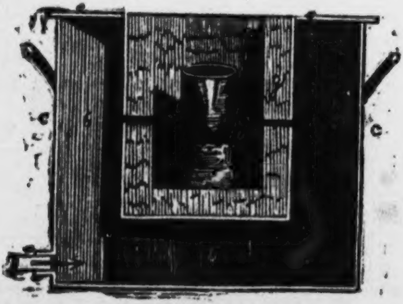
When the substance operated on contains other metal besides gold, the addition of charcoal or any other reagent to reduce the litharge is in many cases unnecessary, as litharge readily attacks all the sulphides, arsenio-sulphides, etc., and oxidises nearly the whole of their constituents, with the exception of silver and gold, whilst a proportionate quantity of metallic lead is at the same time set free. The slags thus formed contain the whole of the excess of litharge added, whilst the button of alloy produced is extracted by breaking the crucible, after it has been allowed to cool, and is then subjected to the process of cupellation. The proportion of oxide of lead to be added to ores of this description necessarily varies with the amount of oxidisable substances present, but should in all cases be added in excess, since, if the slags retain any traces of an alkaline sulphide, the whole of the gold contained in the mineral will not be present in the button of alloy obtained. For the assay of iron pyrites, about thirty parts of oxide of lead are necessary; whilst for mispickel, zinc blende, copper pyrites, gray cobalt, and sulphide of antimony, from fifteen to twenty-five times their weight only may be employed.

The only objection to be made to this method of assay is the large amount of lead which is produced for cupellation; since pure iron pyrites affords, when thus treated, eight and a half parts of lead, whilst sulphide of antimon[illegible]nd grey copper ore yield from six to seven parts. [illegible]is inconvenience may, however, be obviated, by effecting the partial oxidation of the mineral by the aid of nitrate of potash or saltpetre; by the skilful use of this reagent a metallic button of almost any required weight may be obtained. Should the nitre be employed in excess, it would determine the oxidation of all the metallic and conbustible substances contained in the mineral. To this the gold alone would be an exception; but from the comparatively small quantity in which that metal exist, it could not thus be obtained in the form of a button.

When, however, the mixture contains at the same time a large excess of litharge, and the nitre has not been added in sufficient quantity to decompose the whole of the sulphides present, a reaction is established between the portions of undecomposed sulphide and the oxide of lead added. The exact amount of nitre to be added in these cases will necessarily depend on the nature and richness of the ore treated; but it should in all cases be borne in mine that two and a half parts of nitrate of potash are sufficient to completely oxidise one part of iron pyrites, and that one and a half and two-thirds their weight in the case of sulphide of antimony and galena are respectfullly sufficient to produce the same effect on these ores. In certain cases, however, the process of scorification is to be preferred.

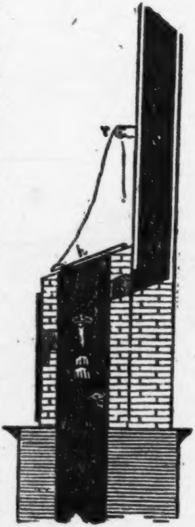
One of the arrangements best adapted for the operations above described, is known by the name of Seftstroem's Blast Furnace, and from its extreme portability, offers great advantages to the travelling assayer.

Such a furnace is represented in the annexed cut, and is formed of two cylinders of sheet-iron placed one within the other. *c* represents the outer cylinder, and *g* the inner one, lined with a coating of fire-clay, about an inch in thickness.



Both cylinders are provided with a bottom, and are fixed together by the top, air tight, in such a way as to leave an equal space between their sides and bottoms, as exhibited in the figure. The smaller cylinder and its lining of fire-clay is pierced near the middle of the sides with eight holes, all pointing towards the centre of the furnace. The crucible to be heated is placed in the middle of this arrangement on a piece of fire brick, kept in its place by a little fire clay. The air is blown into the opening *a*, which is connected with the nozzle of a double-action bellows, and is thus compressed into the space *b*, and thence driven through the holes *o* into the cavity of the furnace. Instead of using bellows a current of air may be advantageously supplied by means of a rotating fan, similar to those which are employed for domestic purposes.

When this blower is employed, the nozzle should be held at a distance of about a quarter of an inch from the orifice *a*, which in this case must be made slightly funnel-shaped. The heat thus produced is exceedingly intense: so much so that a furnace having an internal diameter of six inches, and externally as large as an ordinary hat, is capable of melting, with the greatest ease several ounces of cast iron. The fuel used for a small furnace of this kind should be charcoal broken into pieces of about the size of nutmegs. This uniformity is readily obtained by breaking the fuel into fragments of nearly the size required, and then sifting it through two sieves, one of which retains all the pieces which are too large, whilst the other lets through all those which are too small. When, however, the materials for its erection can be obtained, the ordinary wind furnace is to be preferred. The annexed cut represents this apparatus.



Whenever it can be conveniently managed, it is desirable that the ash-pit of the furnace should be placed beneath the floor of the room in which it is situated, and communicate either with the cellar of the house or with an opening made in front, which for the sake of the draught is covered by an iron grating. The inner cavity of the arrangement may be made either round or square; but for large operations round furnaces are generally preferred, although, for the purposes of assaying, square ones are more commonly used. The cross section of this furnace is a square, of which each side may measure twelve inches. At *e* is the grate, consisting of several bars of wrought iron, united together and turning on a hinge. The side of the grating opposite to the hinge rests upon an iron bar *p*. This bar is moveable, and can be withdrawn on pulling a knob on the outside of the furnace. When this is done the grate falls perpendicularly on its hinges, and allows the fuel to escape into the ash-pit beneath. The mouth of the furnace is closed by an iron plate *h*, lined with fire-clay, and fastened to a chain, by the aid of which and the pulley *r* it can be opened, when it is necessary either to throw in fuel or to stir the fire. In this plate there is a small hole *n*, which can be closed by a movable iron cover. This is used for occasionally viewing the interior of the furnace. From the internal cavity the heated gases pass into the chimney *c* by the canal *b*; the cross section of the flue, like that of the furnace itself, is a square, and the depth of the furnace, from the fire bars to the moveable cover, may be from two feet to two feet two inches. In many furnaces the cover, instead of being hung on hinges, as above described, is simply made to slide loosely over the aperture. The chimney of a furnace of this description should be at least twenty feet in height.

The opening *b*, between the furnace and the chimney, should be about eight inches by two; but, should it be required, these dimensions may be readily diminished by means of a little fire-clay, and some pieces of refractory brick. The internal lining of such furnaces is commonly made of refractory bricks, bedded in fire-clay, but in default of the former material a lining of fire-clay alone may be readily substituted. The chimney must be provided with a damper for the regulation of the draught.

When this furnace is to be employed to effect a fusion the opening *i* is closed by a piece of fire-brick; another fragment of brick is placed on the grate, and on this stands the crucible in which the experiment is to be made.

When employed for making cupellations, the muffle is introduced through the opening *i*, and rests on the bars *o o*. This furnace is not recommended as being of the best form and dimension that could possibly be used for the purposes of assaying, but is extremely useful for general purposes, and can, if required, be employed for running down large quantities of gold dust.

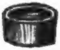
CUPELLATION.—In order to ascertain the amount of the precious metals, *i. e.* the silver and gold contained in the buttons of lead obtained by the foregoing operations, they are subjected to a process called cupellation.

This process is founded on the circumstance that when silver and gold are exposed, in a state of fusion, to the action of the air, they neither give off perceptible vapors, nor are sensibly oxidised, particularly when more oxidisable metals are present.

In order then to obtain the gold contained in the buttons of auriferous lead taken from the crucibles in which the fusions have been conducted, it is only necessary to expose them on some absorbing medium to such a temperature as may oxidise the lead, whilst the gold is not so affected. The oxide of lead, or litharge, which is thus produced, becomes rapidly absorbed by the porous substance by which the assay is supported, and nothing but a small button of gold, or of gold containing a certain quantity of silver, ultimately remains in the metallic state.

These supports are called cupels, and are made of bone-ash, tightly consolidated by pressure in an iron mould, which give to them the form represented by figs. 9 and 10.

A very convenient kind of furnace for the purpose of cupellation is represented by figs. 12 and 13. The first of these figures represents the furnace in elevation, and the second in section. This furnace, as shown in the drawing, is made of sheet iron, thickly lined with fire-clay.



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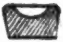

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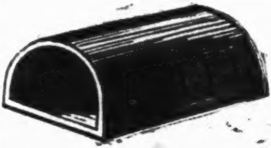
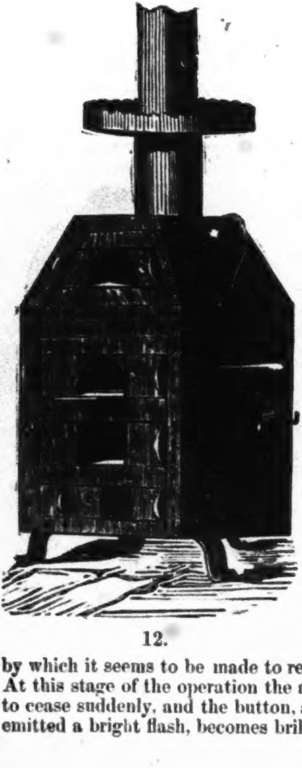
The most important part of this apparatus is the muffle 11, which is a small arched retort of fire-clay closed at one of its extremities, and furnished either with small holes or perpendicular slits in the sides and end, in order to allow of the free circulation of air through its internal cavity. The accompanying wood cut (fig. 11) represents a muffle of this kind, before its introduction into the furnace.

When fixed, it is so arranged that whilst one of its extremities is supported by a proper shelf, the other corresponds to the opening *d'*, to the sides of which it is carefully luted by a little moistened fire-clay. This position of the muffle in the furnace admits of its being readily heated on every side; whilst the opening in its ends and sides admit of the passage of a current of air from the door *d'* into the cavity of the furnace. In this way the interior of the muffle is constantly traversed by a highly oxidising current of air, and the draught of the furnace is kept up by the addition of a long chimney of sheet iron *c*. To light this apparatus a little ignited charcoal is introduced by the opening *d*, and the cavity of the furnace afterwards filled up with the same fuel; the whole of the openings must be now closed by their proper slides, with the exception of the ash-pit *a*. Instead of charcoal, good hard coke, broken into small pieces, may be employed; and when the muffle has become red hot, six or eight cupels, which have been previously drying on the ledge around the chimney, are taken by tongs of the form shown, fig. 14, and placed on the floor of the muffle. This, to prevents its being corroded should any lead be spilt upon it, is previously covered by a thin layer of pounded bone ash.



11.

The opening *d'* is now closed by its doors, so as to prevent the introduction of a current of cold air, and the cupels are thus raised to the temperature of the muffle itself. When this has been done the door is again removed, and into each of the cupels is introduced, by a pair of slender steel tongs, a button of the alloy to be assayed. The door is now a second time closed during a few minutes, in order to facilitate

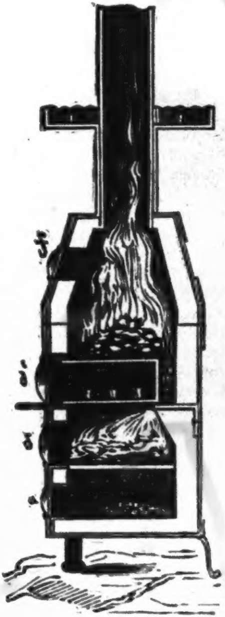


12.

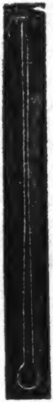
the fusion of the alloy, and on its removal each of the cupels is found to contain a bright convex metallic globule, in which state the assay is said to be *uncovered.* The air thus admitted rapidly converts the lead into litharge, which, as fast as it is produced, is absorbed by the bone-ash of the cupels; and at the same time there arises a white vapor, which is gradually carried off through the openings in the sides of the muffle. An annular stain is also formed around the metallic bath: this gradually extends, and penetrates into the substance of the cupel in proportion as the metallic globule itself diminishes in size. When nearly the whole of the lead has been thus converted into litharge, and absorbed, the remaining bead of rich alloy appears to become agitated by a rapid circular movement, by which it seems to be made to revolve with great rapidity. At this stage of the operation the agitation will be observed to cease suddenly, and the button, after having for a moment emitted a bright flash, becomes brilliant and immoveable.

This phenomena is called the *brightening* or *coruscation* of the metal, and a button remains on the cupel, which, if the original mineral merely contained gold, mixed with the more oxidisable bodies, consists of that metal in a state of almost chemical purity; but if the ore be argentiferous, as well as auriferous, it will be composed of a mixture of gold and silver.

The litharge employed in the first stage of this process, for the purpose of supplying the lead nessary for an essay, in almost every instance contains a certain portion of silver, for which due allowance must be made in the results obtained. In order to do this, it is necessary to ascertain, by a preliminary experiment, in what amount silver is present in the lead reduced from such litharge; and having ascertained the weight of the button obtained, the proper reduction is calculated, and substracted from the button of alloy obtained. When, however, the fusion has been conducted by the aid of nitre,



13.



14.

it is extremely difficult to arrive at accurate results by this means, and consequently in all such cases, as well as when the ore contains silver in addition to gold, recourse must be had to the process of *parting*, which will presently be described. If, after the brightening of the button, the cupel were immediately removed from the muffle, the metallic globule would be liable to *sprout* or *vegetate*, by which its surface would not only be covered by numerous arborescent asperities, but a portion of the metal would probably be thrown off and lost. This effect is only produced when a large portion of silver is present, and it appears to be partly due to the sudden cooling of the surface exposed to the air, which by its contraction compresses the liquid metal contained in the interior, and causes it to burst through the outer coating. The effect is, however, chiefly owing to the expulsion of oxygen gas, as silver is known to absorb that body when in a fused state, and again to part with it at the moment of consolidation. The oxygen in this case would almost appear to be mechanically combined.

To prevent this sprouting from taking place, and to guard against the loss of metal that is liable to ensue, the cupel on which the button has brightened should be immediately covered by another, which has been kept red hot for that purpose. The two are now withdrawn together, and allowed to remain on the ledge before the muffle, until the metal has been solidified, when the upper cupel may be removed, and the globule of rich alloy detached and weighed.

From the circumstance that silver is sensibly volatile at elevated temperatures, it becomes necessary to make cupellations of the buttons obtained from ores containing that metal at the lowest heat at which the absorption of the litharge can be readily determined. If, however, the cupel be not made sufficiently hot, an annular incrustation of crystallised litharge will begin to accumulate around its edges, and if at this point the fire be not immediately attended to, the deposit of oxide spreads rapidly over the whole surface of the metal, and the further progress of the operation becomes entirely stopped.

In case of this happening, the mouth of the cupel must for a few minutes be closed by its door of sheet iron, and the heat of the muffle raised by the addition of fresh fuel: should this fail to uncover the bath, a small quantity of powdered charcoal may be sprinkled over its surface.

The temperature best suited for cupellation is obtained when the muffle and the enclosed cupels are at a full red heat, and the vapors which arise from the alloy curl gradually away, and are promptly removed by the draught. When the muffle is heated almost to whiteness, and the vapors rise to the crown of the arch, the temperature is too high, and when on the contrary the fumes lie over the bottom, and the sides of the openings in the muffle begin to darken, a little more fuel must be added through the door *f*, and the heat gradually raised. When the operation is conducted at a proper temperature, the cupel should be of a cherry-red color, and the fused alloy very bright and convex. At the commencement of the operation the heat must be a little raised, for the purpose of fusing and uncovering the button, and just before the globule is about to brighten, a slight elevation of temperature is again advantageous, but if a proper heat has been kept up during the progress of the operation, this is by no means necessary.

The success of an experiment is likewise considerably influenced by the force of the draught passing through the muffle. When the current is too rapid, the cupel becomes cooled, and the lead is oxidised with greater rapidity than it should be: in this case the litharge produced is not absorbed by the test as fast as it is generated, and consequently the surface of the alloy is covered by a coating of oxide of lead, by which it ultimately becomes protected from any further oxidation. When, on the contrary, the current is too feeble, the assay remains a long time in the muffle, and, if silver be present, a large amount is lost by sublimation.

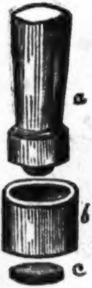
If an assay has been properly conducted, the risidual button is round, bright, and smooth on its upper surface, and beneath should be crystalline, and present a frosted metallic appearance; it is easily detached from the cupel; and readily freed from any adhering litharge. This globule is now removed by a pair of fine steel forceps, and slightly crushed between the jaws of a pair of pliers, by which the oxide of lead, which frequently attaches itself to it, becomes pulverized, and is removed by scratching with a small brush made of stiff hogs' bristles. When the buttons obtained on the cupels are extremely small, they are best flattened on a small anvil or steel stake, before being cleaned by the brush. The flattened discs are then examined by the aid of a powerful lens, in order to be sure that their surfaces are perfectly clean, and afterwards weighed in a balance capable of turning with 1-1000th of a grain weight. For the purpose of weighing the ore previous to its fusion with the litharge, as well as for ascertaining the weight of the button of lead obtained, when that is required, a pair of common apothecaries' scales may be conveniently employed.

When, in addition to gold and lead, the button obtained by the fusion likewise contains copper, it must be cupelled like the similar alloys of silver and lead, but as copper possesses a much greater affinity for gold than for silver, a proportionately large addition of lead must be made, in order to ensure the production of a button in which copper is not present. This proportion varies in accordance with the composition of the alloy operated on, as shown in the following table, in which is indicated the total amount of lead to be added to the various alloys of gold and copper, in order to obtain the former metal in a perfectly pure state.

Proportion of Gold contained in the Alloy.	Quantity of Lead necessary to completely remove the Copper by Cupellation.
1000 thousandths	1 part
900 “	10 “
800 “	16 “
700 “	22 “
600 “	24 “
500 “	26 “
400 “	34 “
300 “	
200 “	
100 “	
50 “	

Instead of using the cupellation furnace described at the beginning of this chapter, a small one, made of fire-clay, and bound with iron hoops, may sometimes be used with advantage. These small clay furnaces are, however, liable to be broken, and are consequently inconvenient when they have to be carried to any considerable distance. The best crucibles to be employed for the fusion of the ore, are either the Cornish, or those known by the name of London pots, although, when made of good material, I usually prefer the latter. Those called four-inch pots are of the most convenient size.

Cupels.—The manufacture of cupels is an extremely simple operation, and is thus conducted. The bone-ash obtained by burning bones, either in heaps, or in the larger assay furnace, is first pounded, and then passed through a sieve of fine wire gauze, and afterwards mixed with water until sufficiently moistened to retain the marks of the fingers when taken up and tightly squeezed in the hand. To give to the cupels, when made, a certain degree of firmness, a little carbonate of potash is sometimes added to the water with which the bone-ash is moistened. The amount of alkaline carbonate required for this purpose is exceedingly small, since a fragment of the size of a hazel nut will be amply sufficient to add to a pint of water. Instead of water, some persons use sour beer, and thus dispense with the use of any kind of alkali. The form



15.

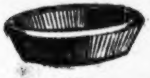
of mould best adapted for the manufacture of cupels is represented by fig. 15, and consists of a beveled steel ring, *b*, and a die, *a*, made of the same metal, and fitted with a wooden handle. To make a cupel, the cavity is nearly filled with moistened bone ash, which is first compressed slightly by the hand, and afterwards by the die, which is tightly driven into the ring by the use of such a mallet as is shown in fig. 16. When sufficiently consolidated the die is withdrawn, and by introducing a wooden cylinder which exactly fits the aperture, the cupel is without difficulty removed. The use of this wooden cylinder is sometimes liable to crumble the edges of the cupel, and for this reason a loose plate, *c*, exactly fitting the bottom of the mould, is frequently introduced, before the bone ash is placed in it. When this precaution is token, the iron protects the bottom of the cupel, and enables the operator to use considerable force without injury to the edges of the newly made test. This iron plate must of course be replaced each time a cupel is made, and, with the test before it, is again forced out of the mould.

Scorification.—Scorification, like the fusion of the ore with litharge, has the effect of producing an alloy, which may be subsequently passed to the cupel, and a very fusible slag, composed of oxide of lead, and all the other substances present, with the exception of the precious metals. In the fusion with litharge, however the oxidation of the various substances which are to be removed is produced by the action of the oxygen contained in the litharge itself, whilst an equivalent amount of lead is reduced to the metallic state, and enters into combination with the gold and silver which the

16.

mineral may contain, to furnish the required alloy. When, on the contrary, the process of scorification is adopted, these substances are oxidised by the aid of atmospheric air, whilst the litharge necessary for the fusion of the earthy and siliceous matters is itself formed by the oxidation of a portion of the metallic lead which is added to the ore to be assayed. For this operation, instead of using cupels made of bone-ash, small vessels, of the form represented in fig. 17, and made of close-grained fire clay, are employed. These scorifiers are heated in the muffle of an ordinary assay furnace, and as many assays may be introduced at one time as there is room for in the muffle.

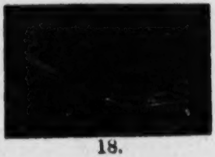
Before introducing the scorifiers into the furnace, they are each charged with a determined weight of the mineral to be operated on, reduced to the state of a fine powder, and intimately mixed with a certain quantity of finely granulated lead. They are now placed in the muffle, and there strongly heated during a quarter of an hour, with the door at the mouth closed. At the expiration of this time the lead will be found to be melted, and the mouth of the muffle is again opened. The current of heated air which now passes through the muffle immediately begins the process of roasting, which is continued tranquilly, without there being any necessity for continual stirring, as is frequently the case when substances are roasted in the muffle without the addition of lead. The effect of this oxidation is to produce a slag on the surface of the metallic bath, and this, which at first accumulates around the edges of the scorifier, soon becomes extended over its whole surface. These slags, which at the commencement of the operation are frequently solid, gradually become soft, and finally remain in a perfectly liquid state; since, in proportion as the operation advances, the quantity of oxide of lead which they contain becomes more and more considerable.



17.

When it is thought that the scorification has been sufficiently advanced, the fused matters are well stirred with a slender iron rod, for the purpose of mixing with the mass any hard and pasty substances which they may contain, and which might otherwise remain attached to the sides of the vessel. After this the muffle is for a short time strongly heated, and the slags thereby rendered as completely liquid as possible. The point at which the scorification has been sufficiently advanced may be recognised by placing in the mixture a small iron poker, previously heated to redness; and when, on withdrawing this, it is found covered with a slight film of scoria, which runs off without forming a small solid drop at the end of the rod, the operation may be considered complete. This condition of the slag is indispensable, in order that no metallic buttons may remain adhering to the sides of the vessel.

When this point has been attained the operation is terminated, and the scorifier immediately withdrawn from the fire by means of proper tongs, and the alloy poured into a mould of the form represented in fig. 18.


18.

When cold, the metallic button is readily separated from the slags, and may be passed on a cupel in the usual way.

The process of scorification is, without exception, applicable to the assay of all kinds of auriferous and argentiferous ores, and is at the same time one of the most exact methods that can be employed. When the gangue or matrix of the ore assayed is siliceous, the oxide of lead, which is formed by the roasting of the metallic lead, combines with the silica to form a fusible silicate; whilst the remainder of the lead, which escapes oxidation, unites with the silver and gold which may be present in the ore. When these metals are in combination with other metallic substances they absorb oxygen from the atmosphere, and the oxides produced combine with the litharge formed at the same time, and thus gives rise to various fusible compounds.

The chief and most valuable feature of the process of scorification is, that however small may be the proportion of lead employed, the slags produced never contain any oxy-sulphides at the close of the operation; and from this it follows that they rarely retain the most minute trace of either gold or silver. We have, moreover, seen that the assay of the sulphides and arsenio-sulphides by means of litharge is attended with considerable inconvenience, from the amount of that oxide which it is necessary to employ; since for the first 30 parts, and for the second as much as 40 parts, are sometimes required, and if these amounts be not respectively added the slags will retain sulphides in combination, by which the results of the experiment will be more or less vitiated.

PARTING.—When, as is frequently the case, the button produced by the fusion of the ores contains, in addition to lead and gold, a certain proportion of silver together with traces of copper, it must be cupelled at a moderate temperature, and, if necessary, an additional quantity of silver added. By operating in this way the button obtained on the cupel consists of an alloy of silver and gold, which is afterwards treated with an excess of nitric acid; this effects the solution of the silver, and leaves the gold untouched in the form of a brown sponge, in the bottom of the flask in which the experiment has been conducted. In order, however to obtain perfectly exact results, it is necessary that a certain relation should exist between the amount of the two metals of which the alloy is composed; since, if the silver be not present in sufficient quantity, the mixture is not completely attacked by nitric acid; whilst on the other hand, when too large a proportion of this metal is added, the gold remains in a pulverulent form, which renders its collection for the purpose of weighing extremely difficult.

This operation, which has received the name of *parting*, is found to succeed most fully when the alloy contains a little less than three parts of silver to one of gold, and therefore, in all cases where the greatest exactitude is required, the addition of silver must be so managed as to agree as closely as possible with this proportion. If the alloy contain less than two and a-half parts of silver to one part of gold, the solution of the silver is not readily effected, as in this case some of its particles are so enveloped in gold as to resist for a long time the action of the strongest nitric acid.

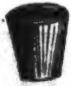
The operation of adding the proper amount of silver to an alloy of gold to reduce it to the best standard for the process of parting, is called *inquartation*. The quantity of silver necessary for this purpose is estimated in accordance with the approximative composition of the alloy produced by direct cupellation. This may be judged of either by the touchstone, as will be presently described, or in many instances by a simple inspection of its color and hardness.

The inquarted button, when obtained, should be carefully flattened with a polished hammer (as 1. in fig, 16) on a steel anvil, and afterwards attacked in a small flask or test tube by nitric acid of specific gravity, 1-15. After being boiled with acid of this strength until the red vapors at first given off have ceased to be evolved, the residue is again heated to ebullition during from ten minutes to a quarter of an hour in acid of specific gravity 1-25. At the expiration of this time the acid is carefully poured off, and the residual gold, after being carefully washed with distilled water, is transferred to a thin porcelain capsule, from which the water is partially removed by pouring, and the remainder evaporated by exposure to a gentle heat. After being heated to redness the pulverulent gold may be either weighed directly in an accurate balance, or be folded in a small piece of poor lead-foil, and again passed to the cupel so as to obtain it in the form of a pure metallic globule. It is of the greatest importance that the acid employed for the above operation should be perfectly free from chlorine.

Assay of Gold Dust and Artificial Alloys.—As in these cases the standard operated on is in most instances approximately known without having recourse to any preliminary investigation, the operation usually commences by fusing the alloy in a cupel with about five times its weight of poor lead, and then adding the amount of pure silver necessary to bring the mixture to the proper composition. After having in this way obtained a button by cupellation, it is first flattened on an anvil, and afterwards annealed by being heated to redness in the muffle, and allowed to cool. It is then drawn out into the form of a long slip by being repeatedly passed between the rollers of a small flatting-mill. During the progress of this operation the metal requires to be a second time annealed, and when sufficiently reduced in thickness should represent a metallic ribbon of about three-eighths of an inch in width, and three inches in length. A convenient weight of alloy to operate on is 12 grains, as this, as will be shortly explained, bears a simple relation to the carat. In laminating the cupelled button, it is, however, necessary that it should be reduced to a suitable thickness, so that on the one hand the silver may be readily dissolved, whilst on the other, if the lamination be carried too far, the gold remaining at the close of the experiment will not possess sufficient coherence to admit of being conveniently removed and passed to the muffle. The strip of alloy thus prepared is now wound in the form of a spiral around a piece of iron wire, or the barrel of a quill pen, from which it is removed to a small glass matrass capable of holding about six fluid ounces, which, with the tongs used for holding it, is shown in fig. 19. Instead of employing a flask of the form here represented, a small bulb-shaped matrass with a long neck is frequently used: this latter form is now generally adopted by the best assayers of bullion, both on the continent and in this country. About two ounces of nitric acid of specific gravity 1·15, are now added, and the whole exposed to the temperature of ebullition until red fumes have ceased to be given off; when this occurs the first liquor is carefully poured off and replaced by the same quantity of acid having a specific gravity of 1·25; with this the residue is briskly boiled for another ten min-

19.

utes, after which it is poured off, and the remaining gold carefully washed. The flask is now entirely filled with distilled water, and after covering the neck with the thumb, so as to prevent the escape of any of the liquid, it is so inclined as to allow the cornet of spongy gold, which retains the form of the original alloy, to descend slowly and without breaking to the neck of the matrass. The metallic spiral is now carefully allowed to drop into a small earthen crucible, fig. 20; the water is carefully poured off, and when quite dry the whole is heated in the muffle to bright redness. In these operations the stronger acid is not at first applied, because it is liable, by its rapid action on the silver, to divide the gold in the form of powder; but some of the best assayers are in the habit of using acid of the density of 1.20, and in this case, if the operation be skillfully conducted, there will be no need of any subsequent addition of stronger acid. When the attack has been carefully conducted the gold remains in the form of a friable brown sponge, having very nearly the same dimensions as the original spiral of alloy; on heating this, however, as before described, it contracts very considerably, and at the same time acquires the color and consistence of ordinary malleable gold. The results thus obtained differ from one-quarter to one half thousandth from the actual truth, and are therefore sufficiently exact for every commercial purpose.



20.

The Touchstone.—When the apparatus and re-agents necessary for the carrying out of a complete assay cannot be procured, a very near approximation to the truth may be obtained by the use of the touchstone; and as the materials employed for these operations are extremely portable, its use is sometimes attended with considerable advantage. This process essentially consists in rubbing some convenient part of the object to be examined on a hard siliceous stone of a dark color, on which it thus leaves distinct metallic traces; from the aspect of these marks, and their behavior when treated with nitric acid, either with or without a slight addition of muriatic acid, the operator judges of the value of the gold subjected to examination. The material employed for this purpose, and which is generally known by the name of touchstone, is a coarse-grained species of quartz colored by bituminous matter, and of which large quantities are found in Saxony, Bohemia, and various other localities.

In order to be enabled to judge of the value of an alloy from the nature of the marks left by it on the surface of the stone, the assayer is furnished with a series of small bars or touch needles, formed of alloys either of copper and gold, or of silver and gold, as the case may be, and of which the composition is accurately determined.

Table showing the Quantity of gold to the ton of ore corresponding to the Weights in grains obtained from 400 grains of mineral.

If 400 grains of Ore give Fine Gold.	One ton of Ore will yield			If 400 grains of Ore give Fine Gold.	One ton of Ore will yield.		
grs.	oz.	dwts.	grs.	grs.	oz.	dwts.	grs.
.001	0	1	15	.200	16	6	16
.002	0	3	6	.300	24	10	0
.003	0	4	21	.400	32	13	8
.004	0	6	12	.500	40	16	16
.005	0	8	4	.600	49	0	0
.006	0	9	19	.700	57	3	8
.007	0	11	10	.800	65	6	16
.008	0	13	1	.900	73	10	0
.009	0	14	16	1.000	81	13	8
.010	0	16	8	2.000	163	6	16
.020	1	12	16	3.000	245	0	0
.030	2	9	0	4.000	326	13	8
.040	3	5	8	5.000	408	6	16
.050	4	1	16	6.000	490	0	0
.060	4	18	0	7.000	570	13	8
.070	5	14	8	8.000	653	6	16
.080	6	10	16	9.000	735	0	0
.090	7	7	0	10.000	816	13	8
.100	8	3	8	20.000	1633	6	16

Gold is seldom found in nature in a pure state, and for the purposes of the arts is alloyed with a small quantity of either silver or copper, by which its hardness as well as its fusibility are considerably increased.

In this country the standard of the alloys of gold is calculated in fractions of unity expressed in carats. Unity is supposed to be divided into twenty-four carats, whilst the carat itself is subdivided into thirty-two thirty-secondths; so that unity may be considered as made up of seven hundred and sixty-eight thirty-secondths of a carat. In this way the gold coinage of the United Kingdom is said to have a standard of twenty-two carats; or, in other words, a sovereign consists of an alloy in which, in every twenty-four parts there are twenty-two parts of fine gold, and two parts of alloy. It is for this reason that for the assay of bullion, twelve grains of the substance are conveniently operated on, since every half grain of fine gold found by experiment will evidently correspond to one carat in the composition of the alloy. The various subdivisions of the carat are represented by fractions of a grain, and the true standard is thus strictly and readily determined. It is needless to remark, that in all the foregoing operations the greatest accuracy is required, both in making the various weighings, and also in the fusion and separation of the buttons. It is likewise advisable in all cases to make at least two separate experiments on every sample examined; and if these should not agree to within two or three-thousandths of a grain, other assays must be made until the desired approximation has been obtained.

Specific Gravity.—The specific gravity of gold having been mentioned in the former part of this book as a means of distinguishing that metal from other substances of near the same color, it is necessary that the meaning of the term specific gravity should now be explained, as also the methods by which the specific gravities of bodies may be conveniently ascertained.

By the specific gravity or *density* of a substance is understood its weight as compared with that of an equal bulk of some other body taken as a standard of calculation. In the case of solids and liquids, distilled water, at the temperature of sixty degrees Fahr., is taken as this point of comparison ; but the densities of the gases are usually estimated in relation with common air taken as unity.

In order to determine the specific gravity of a body, it is necessary to ascertain its weight when weighed in air, and also to learn how much it loses in weight by immersion in water. If we call its weight in air W, and its weight when suspended in water w, it is evident that $W-w$ will represent the weight of an equal volume of that liquid, as whenever a solid is placed in a liquid that covers the top of it, it must necessarily displace precisely its own bulk of the medium in which it is situated. The specific gravity of a body being, then, its weight in comparison with an equal bulk of some other substance taken as unity, it will readily be obtained from the above data, and is nothing more than the relation existing between W and $W-w$, which will consequently be represented by $\dfrac{W}{W-w}$.

The most common method of taking specific gravities, when large pieces of the substance to be operated on can be readily procured, is by means of what is called the hydrostatic balance (fig. 22), of which the pans are

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suspended by strings of unequal length. In order to obtain a density by this instrument, the substance to be operated on should be suspended by a hair or filament of silk to the shorter pan, which has a hook attached to its under side for that purpose. Weights should now be added in the other pan until the equilibrium is restored; and when this takes place the weight W will be noted as that of the substance in air. To obtain the corresponding weight of an equal bulk of water at the temperature of sixty degrees Fahr., a vessel of that liquid is now placed under the shorter pan in such a way that the suspended fragment of which we desire to know the density may be completely immersed in it, and weights are to be removed from the other pan until the equilibrium be again restored. The second weight thus obtained w, deducted from W, ascertained by weighing the substance in air, gives the weight $W-w$ of an equal volume of water, and the required specific gravity $\frac{W}{W-w}$ is at once obtained by dividing the weight in air by this difference. When it is required to conduct these operations with great accuracy, it is necessary to employ a very delicate balance, and to remove any air-bubbles that may attach themselves to the substance when placed in water, by means of a camel's hair brush. The temperature of the water in such cases should also be constantly kept at sixty degrees, and any deviation of the barometer from thirty inches should be duly allowed for. In cases where but small fragments of a substance can be obtained, the instrument called the specific gravity bottle may be employed. This is nothing more than a common bottle of which the stopper, nicely fitted by grinding, is traversed by a capillary tube, and so arranged that it cannot sink beyond a line marked upon the neck of the phial. By this means it is easy to obtain a constant weight of water in the instrument, since, if it be filled beyond the line and the stopper afterwards be forced into it, the residual liquid will escape through the capillary tube, and the bottle remain exactly full. In order to take a specific gravity by the aid of this phial, it should first be weighed when full of water; a counterpoise equivalent to the weight of the bottle being placed in the opposite scale-pan. The substance to be examined must then be weighed in air, and afterwards dropped into the phial, care being taken to avoid the loss of the most minute particle. The stopper is now replaced, so that the bottle may again remain exactly full, and the whole is reweighed. The difference between the weight of the bottle of water, W, added to the weight of the substance in air, W' or $W+W'$; and that of the weight of the bottle of water, w, when containing the fragment to be examined, is evidently $W+W'-w$, and the specific gravity sought will, consequently, be expressed by

$$\frac{W+W'}{W+W'-w}.$$

The following example may probably render the above explanations more readily understood. We find that the bottle filled with distilled water weighs 995·74 grains $=W$.

Another substance, which is supposed to be gold dust, weighs in air 105·30 grains $=W'$. The bottle with the supposed gold dust and water together, weighs 1095·52 $=w$. The united weights of the substance and bottle of water together being 1101·04 grains $=W+W'$, the weight of the equivalent volume of water displaced will be $1101{\cdot}04-1095{\cdot}52=5{\cdot}52=W+W'-w$. It consequently follows that the specific gravity of the substance is—

$$\frac{105{\cdot}30}{5{\cdot}52} = 19{\cdot}07 = \frac{W+W'}{W+W'-w}$$

The above result shows, then, that the substance examined was really gold dust, and but little mixed with any kind of alloy.

Instead of operating as above described, the density of any finely divided body, such as gold dust, may be readily and accurately determined by the following process:

The substance is first weighed in air, and then placed in a specific gravity bottle of known capacity, and the bottle carefully filled from a graduated pourette, up to the point marked on its neck. On consulting the pourette, every division of which may represent one grain of distilled water, it is at once seen how many grains of water have been required to fill the bottle, when containing the known weight of gold, up to the mark on its neck. On deducting this from the ascertained capacity of the bottle, the weight of the displaced water is at once seen. The weight of the substance in air is now to be divided by this result, and the specific gravity of the body examined is at once obtained.

The advantages of this method under circumstances in which distilled water cannot be obtained is very obvious, as not only will any liquid not acting on the substance under examination answer for the experiment, but the results found are also perfectly independent of both temperature and pressure.

From the known specific gravity of gold, as well as that of the quartz rock with which it is commonly associated, it becomes easy after determining the density of the mixture, to ascertain by calculation the relative amount of each present in any particular specimen.

To find the proportions of Gold in a mixture of Gold and Quartz.

The specific gravity of the gold = 19·000
The specific gravity of the quartz = 2·600

These numbers can be corrected when experiment shows the specific gravities to be different.

A. Ascertain the specific gravity of the mixture of gold and quartz. Suppose it to be 8·067.

B. Deduct the specific gravity of the mixture from the specific gravity of the gold; the defference is the ratio of the quartz by volume:

$$19{\cdot}000 - 8{\cdot}067 = 10{\cdot}933$$

C. Deduct the specific gravity of the quartz from the specific gravity of the mixture; the difference is the ratio of the gold by volume:

$$8{\cdot}067 - 2{\cdot}600 = 5{\cdot}467.$$

D. Add these ratios together, and proceed by the rule of proportion. The product is the per-centage of gold by bulk.

10·933 + 5·467 = 16.400.

16·4 is to 5·467 as 100 is to 33·35

E. Multiply the per-centage of gold by bulk, by its specific gravity. The product is the ratio of the gold in the mixture by weight :

33·35 × 19·00 = 633·65.

F. Multiply the per-centage of quartz by bulk, by its specific gravity. The product is the ratio of the quartz in the mixture by weight:

66·65 × 2·60 = 173·29

G. To find the per-centage add these ratios together, and proceed by the rule of proportion :

633·65 + 173·29 = 806·94.

806·94 is to 633·65 as 100 is to 78·53.

Hence a mixture of quartz and gold, having the specific gravity of 8·067, contains 78·53 per cent. of gold by weight.

The Geology of California.

So far there has been no thorough and systematic geological survey of California, although under the able guidance of Professor Whitney, our State Geologist, one is progressing. We can therefore give the results of only partial observations, made by competent geologists at various times since the settlement of California by the Americans. Professor Blake, who made a minute geological investigation of the region he traversed, says:

"With the exception of the diluvial strata, the whole geological formation of the Sierra range consists of igneous and metamorphic rocks: the former are mostly porphyritic in the lower hills, whilst higher up trachytic rocks are frequently met with. The metamorphic rocks consist of micaceous schists, slates both talcose and micaceous, metamorphic sandstones and limestones, with occasional beds of conglomerate. The stratified rocks have been much displaced; it is rare to find them with a dip of less than seventy degrees, and they are generally very nearly perpendicular. The strike of the beds in that section to which my observations have been confined (between the Stanislaus and Yuba Rivers) is extremely uniform, being from five degrees to ten degrees W. of N. and E. of S.- The extent of the diluvial deposits is commensurate, or nearly so, with that of the gold-bearing region, in that part of the country which I have examined. They are found in a belt of land from thirty to sixty miles broad, and running parallel with the axis of the range; and, from facts that I have ascertained from others, I have no doubt but that they exist throughout all the gold-bearing region, both north and south. These diluvial deposits are met with as we advance towards the lower hills of the Sierra, extending frequently some miles into the plain. They are often of considerable thickness, and frequently rest on tertiary rocks On approaching the foot of the lower hills, the conglomerate and gravel are found in greater abundance, the pebbles and boulders are larger, and contain more of the heavier rocks. They are seen also covering extensive valleys or flats of many miles in extent, enclosed by low ridges of porphyry and slate, which rise rather higher than the surface of these beds. On ascending from the lower hills towards the mountains, the diluvial beds no longer occupy the same relative position; occasionally deposits of rounded stones can be found in the valleys and on the sides of the hills, but when this is the case their origin can always be traced to deposits existing on the tops of the surrounding hills, from which they have been brought down by the action of the causes now at work. As we ascend towards the axis of the chain, these deposits become more extensive, and at a distance of twenty or thirty miles from the lower hills, they are found occupying the crests of almost all the highest ridges in the country; but besides being found on the crests of the ridges, where their extent frequently does not exceed a few yards in breadth, they are also met with covering in the extensive elevated flats which exist on the benches between the different watercourses, forming continuous beds of some miles in extent, which are rarely interrupted by the protrusion of any of the older rocks. Where found in these elevated situations, the lower hills and valleys are entirely free from them; frequently a large section of the country will be enclosed from two high ridges capped by deposits, and diverging from a common point; in the intervening space will be seen many secondary ridges, sometimes fifteen or eighteen hundred feet high, formed entirely of the older rocks, no traces of deposits being found on their surface, nor in the ravines that lead from them.

"The depth of these deposits is extremely variable. Sometimes nothing more than a trace of them in a few rounded pebbles lying on the top of a ridge is found; the valleys and ravines in the neighborhood containing their disintegrated elements in considerable quantities. In other instances, particularly where spread out over elevated flats, they are of a moderate and pretty uniform thickness for a considerable distance, varying from two or three feet to a few inches, and this too, in positions where the surface could not have been exposed to any great amount of denudation. They are again found many hundred feet in thickness, composed of superimposed strata of different mineralogical constitution, generally horizontal and conformable with each other.

"The localities where these deposits are met with most extensively disclosed, and that have been worked, are at Nevada and at Mokelumne hill. At the former place they form the crest of a high mountain called the Sugar Loaf, full 2,000 feet above the level of Deer Creek, the upper 600 feet being formed entirely of diluvial strata. At Mokelumne-hill they are also some two hundred feet deep, forming here also the summit of a high and isolated mountain. The elements of which they are composed differ considerably in different localities, although there are through the whole series many points of resemblance. In the lower valleys and flats, between the ranges of the lower hills, they appear to consist of beds of gravel, containing occasional boulders of quartz, and the harder rocks. On the elevated flats higher up in the mountains, the surface of these deposits is generally covered by a reddish loam, mixed with small gravel; whilst reposing on the bed rock, and a few inches above it, is found a stratum containing large boulders and gravel, the boulders being principally quartz. On the top of the hills and the crests of the ridges, where they generally attain their greatest thickness, we find them composed of many distinct strata, lying nearly horizontal, and conformable with each other, and generally also with the surface of the underlaying rock. In these situations, the most superficial stratum is composed of a mass of extremely hard conglomerate, containing principally trachytic rocks, imbedded in a hard argillaceous cement. It is this hard stratum that has undoubtedly preserved the underlaying beds from the destructive influences which have so powerfully acted on the surrounding rocks.

"At other points the whole series consists of conglomerates and soft friable sandstone. In the lower strata, quartzose conglomerates, with an argillaceous cement or loose quartzose gravel, always prevails, with large boulders of quartz, weighing frequently two or three tuns, having their surface worn smooth and the angles rounded. The deposits of these heavier rocks have been formed on spots which were evidently lower than the level of the surrounding rocks; whilst on these parts which were higher at the time the deposits were formed, the higher trachytic rocks are found. As far as my researches have extended, the more quartzose conglomerates have been invariably found on the erupted rocks, whilst the stratified rocks which they had upheaved were only covered by the trachytic conglomerates. The pebbles of which these conglomerates are composed present specimens of all the harder rocks. Metamorphic sandstones, clinkstone, trap porphyrics, and quartz make up the larger part of the mass. They are all perfectly rounded, but in the lower deposits are so soft, that, with the exception of the trap and quartz, they generally fall to pieces on exposure to the air. The strata, as before observed, are nearly horizontal and conformable; if they have any dip it appears to have been owing to the slope of the surface of the rock on which they were deposited; in fact, no displacement seems to have taken place in this country since the period of their formation. They lie perfectly horizontal over the almost vertical edges of the upheaved slate rocks.

"Pieces of half carbonised wood and impressions of leaves are sometimes found in the clayey beds of these deposits; and at Nevada, it is said that the trunk of a tree had been traced for some distance in the clay, at forty feet below the surface. I have obtained specimens of wood, and also imperfect impressions of leaves, taken out four or five hundred feet below the surface of the ground, and three hundred and fifty feet from the side of the hill at the same locality. The wood belongs to one of the Coniferæ, but I was unable to determine the character of the leaves. A tooth also has been found in some of these deposits. I have not seen it, but from description it would appear to be a bicuspid belonging to some large Pachyderm. The surface of the rock on which they repose generally presents evidence of considerable abrasion, but I have been unable to detect any regular grooves in it. Where it is more elevated it has been less worn, some of the edges of the slates being not much broken.

" As regards the mineral riches of these deposits, it would appear that gold is found wherever they exist. The ravines coming from the ridges on which they are found are generally extremely rich, and always contain gold, even in places where the deposits themselves have been worked without success. In some places where they have been worked, as much as thirty thousand dollars have been taken from a claim of fifteen feet square ; and there are many instances where ten and fifteen thousand dollars have been taken from claims of the same size. But few of these rich spots have, up to the present time, been opened, yet there can be no doubt but that many still remain to be discovered. Where these deposits are found extending over a large surface on the elevated flats, gold is always met with, generally diffused through the gravel immediately above the rock on which they rest, which yields from fifteen to forty cents per hundred pounds of dirt. There are spots where acres of these deposits have been turned up, in which the gravel never contains less than fifteen cents to the hundred pounds, and generally more. In the valleys in the lower hills, and even on the plains to the west of them, where they are extended over vast tracts of country, these deposits are still auriferous, the gold being very generally diffused, and found in greater quantities the deeper they are worked. At present they will not pay for working, owing to the distance from water, and from the high rate of wages. In one place, where water could be readily obtained, a portion of these deposites, situated to the west of the lower hills, has been worked and has been found to yield from five to thirty cents to one hundred pounds of earth, through an extent of one hundred and fifty acres, the soil being found richer the deeper it is worked."

Professor Whitney writes in regard to the geology of California thus:

"The great valley of California is drained by two principal rivers, the one flowing north and the other south, which unite midway, and make their way through a side-cut in the mountain ranges into the ocean. These streams are the Sacramento amd the San Joaquin, and with their numerous affluents, they drain the auriferous district of California. This immense basin or trough has a length of about five hundred miles, and a breadth of fifty to one hundred. On its eastern rim rise the grand masses of the Sierra Nevada, the continuation of the Cascade Range of Oregon, whose summits are elevated above the limits of perpetual snow. The central axis of the Sierra seems to be made up of granite rocks,through which volcanic fires have occasionally found vent, and piled up lofty masses of debris. This granitic axis is flanked by heavy accumulations of slaty rocks, in which the talcose varieties predominate; these alternate with trappean and serpentine masses, which extend to the valley of the Sacramento, where they are concealed by sedimentary deposits of recent origin. On the western edge of the great valley is the Coast Range, a series of elevations parallel with the coast, and but a few miles distant from it.

"The slates of the Sierra Nevada, forming a belt forty or fifty miles wide, and extending through the valley, are the gold-bearing rocks of the region.

"They form precipitous and broken ranges, cut through by deep gorges through which, in the rainy season, impetuous torrents find their way to the valley. The average fall of the streams from the summit of the Sierra to the valley of the Sacramento is stated by Mr. Tyson, at one hundred and eighty feet to the mile, which would cause a current in the streams when swollen by the melting snows, capable of wearing out these stupendous ravines, some of which exceed 3000 feet in depth.

The geological age of the gold-bearing slates remains undetermined ; but they are similar in lithological character to those of other great gold regions of the world. There can be no doubt that they are very ancient, but whether of azoic or palæozoic age, it is impossible to say with absolute certainty. As similar formations in some parts of the chain of the Andes, have been found to contain fossils of Silurian age, and as this is the period to which the Uralian gold rocks may, beyond a doubt, and those of Australia, with great probability,be referred, it is not improbable the auriferous rocks of California belong also to the palæozoic epoch. Their organic contents have been obliterated, however, and they have assumed a crystalline structure, being everywhere invaded and broken up by igneous masses.

Lower down on the flanks of the Sierra, the summits of the ridges are capped with sedimentary rocks, which rest nearly horizontally on the upturned edges of the slates, showing that they had been deposited after the latter had taken their present form and position. The conglomerates, which, according to Mr. Tyson, cover many of the hills between the Consumes and Calaveras, are found at the height of more than 2000 feet, and consists of pebbles, with a more or less ferruginous cement. They are interstratified with beds of sandstone, beneath which are heavy deposits of indurated clay. The whole thickness of this formation is estimated at 200 feet. This group of sandstone and conglomerates apparently extends under the valley of the Sacramento, and appears again in the ridges of the coast Range, where its stratification is much broken and disturbed. They are considered to be identical, in geological age, with the rocks of similar character which occur in Oregon, and which belong to the Miocene division of the tertiary.

Thus far almost the whole of the gold of this region has been obtained from the superficial deposits, or the loose sand, gravel, and boulders lying upon the rocks in place, and they are found within the mountain districts of the western flank of the Sierra, in the river valleys, and far up in the mountain gorges."

It will be seen, continues Professor Whitney, that the opinions, with regard to the age of the recent stratified deposits, resting on the flanks of the Sierra Nevada, differ; by some they are referred to the tertiary, by others to the drift epoch. If Professor Blake's opinion is correct, and they are really of the period indicated by him, and the true depository of the gold, it is a fact of the greatest interest. In that case, California would present a striking analogy with the Uralian gold fields, and the opinion of Murchison would be fully sustained, that the auriferous detritus is in no way to be confounded with the alluvial deposits of the present day, modern causes having done little more than concentrate the already gold abraded, by washing out the sedimentary matter with which it was imbedded.

W. P. Blake, in the fifth volume of Pacific Railroad Report gives the following classification of auriferous deposits in California:

"1 A coarse boulder-like drift, the result of great abrasion and powerful currents in a great body of water.

"2. A river drift or coarse alluvium, ancient and modern.

"3. Alluvial deposits on flats and over broad surfaces, not confined to river channels.

"4. Lacustrine deposits, made at the bottoms of former lakes or ponds.

"Lacustrine deposits, says he, are found in extensive basin-shaped depressions, in the surface of metamorphic rocks. These depressions have evidently been filled with deep, quiet water, from which thick strata of clay, fine sand and volcanic ashes have been deposited upon the auriferous layer at the bottom. The deposits at Georgetown and Cement Hill are examples of this class. They are more nearly allied to the alluvial deposits of the flats than to either of the other forms under which the auriferous drift appears. The section of the strata at Mameluke Hill shows that the deposition of clay and volcanic ashes from the lake was interrupted, and that a layer of auriferous gravel was spread out over the surface of the clay, after which the former conditions were restored. This alternation or a series of auriferous and non-auriferous materials stratigraphically deposited, forms a well-marked difference between the lacustrine deposits and those of the flats.

"Great changes have been produced in all of these deposits, of denudation and erosion, during and since the elevation of the region to its present level. The old rivers changed their beds, lakes were drained, and new streams cut their way through great deposits of coarse (diluvial) drift, through lacustrine deposits, and across the ancient river courses. But the action of the denuding streams has not been confined to the superficial deposits, either auriferous or tertiary; they have eroded great valleys and canons in the underlaying rocks, both of granite, and limestone, and slate; all are cut through and traversed by long valleys, nearly transverse to the trend of the rocks. These valleys of erosion are on a most magnificent scale, and may be regarded as deep ravines in a formerly unbroken plateau or slope.

"On the forks of the American river, these eroded valleys are from 1,500 to 3000 feet deep, and the traveler who desires to cross from one bank to the opposite side, must wind in a zigzag line down one side, and in a similar manner up the other, traversing a distance, in most cases, of three miles, while in a direct line it may be but little more than a mile from one bank to the other. All this erosion has taken place since the original deposition of the gold; and it is probable that the gold of the streams is derived from the original deposits of coarse drift, rather than from the action of the rivers on the veins, although a very considerable quantity of gold must have been liberated from the veins by their action. The great currents or floods which produced the drift, were much more gradual and wide-spread in their action and appear to have abraded the whole surface, rather than mere lines or channels."

John S. Hittel, in a recent work, briefly speaks of the geological character of the Pacific States, as follows:

"The great bulk of the Sierra Nevada, and the Cascade mountains is composed of granite, covered in places by trap, trachyte, basalt, serpentine, limestone, slate, lava, quartz and diluvium. The Coast Range is a sandstone, with occasional trap and granites. The valley between the Sierra Nevada and the Coast Range, extending from Puget Sound to Tejon Pass—for it was originally one valley, though now separated by the Siskiyou, Umpqua and Calapooya mountains—is a mass of diluvium, from two hundred to five hundred feet deep, lying on tertiary sandstone. The country east of the Sierra Nevada is mostly covered with trap, other eruptive rocks of various classes, and granite."

"Many of the mountains are of volcanic origin, and all the highest peaks were or are volcanic, including Mts. Baker, Rainier, St. Helens and Adams, in Washington territory, Mts. Jefferson, Hood, McLaughlin and the Three Sisters, in Oregon, and Mt. Shasta, Lassen's Peak, the Downieville Butte and Castle Peak, in California. Mount Baker is now an active volcano; Mount Helens emits a constant stream of steam-like smoke, and Shasta sends hot and sulphurous vapors from her summit."

"Beds of lava which have been thrown out by volcanoes, are not rare in the mining districts, and they occupy an important place in the geology of the gold region. In several places they have covered up the beds and channels of ancient streams, thus covering rich deposits of gold; and subsequently they have been left, by the washing away of the adjacent ground, standing as high, narrow ridges, with flat tops and steep sides. The most singular and remarkable 'table mountains,' as they are called, are, one in Tuolumne county, thirty-five miles long, the other in Butte county, about ten miles long."

The latest information we have from competent sources, we find in the report of a lecture, recently delivered by Professor Blake, in San Francisco, which we extract from the *Bulletin*:—"His topic was the anatomy and physiology of our State, which extends over 9½ degrees of latitude, or 650 miles—as far as on the Atlantic coast would reach from Boston to Savannah, and its area but little less than all New England, New York, New Jersey and Pennsylvania put together. As the anatomist first disposes of the bony system of his subject, so the lecturer first considered the mountains of California. They are naturally separated into 5 groups—the Sierra Nevada, the Coast Mountains, the Bernardino Mountains, the Peninsula Mountains, and the Mountains of the Great Basin. That the eye of the audience might assist the ear in comprehending the lay of the land and its character, a large map of the Pacific slope was displayed, on which the mountains were sketched in brick color, the valleys in yellow and the water in blue; and the general impression of the audience was that the brick color had the best of it—that the mountains rule the State. The Sierra, extending nearly 600 miles, from the northern boundary to the head of the Tulare Valley, has no well defined towering summit line, but two or more parallel ranges of nearly equal altitude, forming a double summit; at the north these summit ranges are usually some 20 miles apart, with elevated valleys between. Magnificent Shasta at the sources of the Sacramento, is the most prominent peak, rising into the region of perpetual snows 15,000 to 17,000 feet above the level of the sea. It is an extinct volcano, and appears to belong rather to the Cascade range than to the Sierra Nevada. Geologically this chain, whose western face slopes long and gradually to the valley, but on the east stoops abruptly to the Great Basin, consists of granitic and metamorphic rock. The leading crests are a compact gray syenitic granite, flanked on the west by gneiss and slates down to the foot of the slope. These slates are the prevailing rock after descending from the higher parts of the Sierra. They are very ancient Palæozoic sedementary beds, which have been uplifted from the bottom of former seas and crumpled like so many leaves of a book, till their broad flat surfaces stand on edge, and the hot vapors escaping from below have filled the cracks with quartz and gold. The lecturer paused to correct the absurd opinion that prevails so widely, that the geological character of the country differs totally from that of any other region. Within the past month he had found high up on the slope of the Sierra, the outcrop of a sand-stone, which is known the world over as characteristic of gold and diamond-bearing regions—a peculiar rock which has been found in the Brazils, in the Urals, in India, and in the Atlantic States—and under the lee of which diamonds are almost invariably found. The more modern strata of the Sierra have already been identified as of the same age as those of the East—and the conclusion has been reached, that in the Tertiary times the Pacific and Atlantic oceans were connected north of the tropic zone. Many of the Eocene or early Tertiary species of Mollusks, found fossil at the southern end of the Sierra Nevada, are identical with those that existed at the same period on the former shores of the Apalachian, and are now dug up from the plantations of Georgia and Alabama.

A much more modern system of mountains are the Coast Range or Ranges, for they are not one chief ridge, as formerly supposed, but several, lying parallel with each other, with a series of long parallel valleys between. In our latitude there are three ridges, the western on which our city is enthroned, the central, or Contra Costa range, and the eastern, or Diablo range. There is a similar series at Monterey. The breadth of country occupied by the Coast Ridges and their valleys, varies from 40 to 100 miles. Here and there we find a granitic axis and volcanic rocks, but their principal substance is composed of the tertiary and secondary formations. The strata are disposed in great wave-like flexures, and abound in fossils. They are the very Paradise of palæontologists. Here the lecturer diverted from his course to read the story that the new found coal beds tell of the time when the Sierra Nevada fronted on the Pacific; when there was no Coast Range like a great sea-wall outlying them, when the rivers from the Nevada slope emptied directly into the sea, forming great deltas that supported luxuriant forests now compacted and transmuted into coal; and such he thought probably were the conditions of our region until the period of the Pliocene Tertiary.

The characteristics of the Bernardino range—the southern rim of the Great Basin—more modern than the Sierras, yet far older than the Coast Ranges, and of the Peninsular Mountains that abut almost at right angles upon the Bernardino and lift one perpetual ridge of jagged outlines, until at Cape St. Lucas they sink into the sea, were despatched more briefly. The mountains of the Great Basin are all in parallelism with the Sierra, as are the Rocky Mountains. To the geologist, they seem only like a succession of folds in the strata—or, as one might say, petrified wrinkles in the earth's hide.

Mr. Blake next called attention to the connexion between the direction of the mountain chains and the form and extent of the coast line. The rocky ranges, lying broadside to the sea, preclude it from cutting harbors into the coast, yet it is remarkable, the absence of those deep, precipitous inlets so characteristic of rock-bound coasts in high latitudes. To the fact that there is one notable exception we owe our matchless harbor. The Golden Gate, though not a fiord, is one of the most noteworthy breaks in a coast range known. There does not appear to be any dislocation, or sliding, or "fault" of the strata, but the Gate has more the appearance of a fissure widened by the currents. By the map he clearly showed by what a happy arrangement the Bay of Monterey was formed between the end of one long range and the side of another, and again at San Luis Obispo, how the Pacific excavates inland between the diverging ranges; how the islands that lie parallel to the Santa Inez range of the Bernardino are the peaks of a submerged range, while the Santa Barbara channel occupies the subaqueous valley; how the seven Farallones, all in one straight line, 20 miles of the Heads, are the crest-points of a range that takes to the water off Monterey. So the bottom of our Pacific sea, off many a mile, is all mountain and valley—not like the Atlantic submarine slope, which falls off gently from the flat shore to the deep sea soundings.

To round more perfectly our idea of the hydrography of the coast, Prof. Blake pictured it as it would look lifted 300 feet above its present level. Then the Farallones would stand out the peaks of a continuous range of mountains, on the eastern side of which would lie the harbor of Monterey. New islands would appear, the Bay of San Francisco would be drained, and the great rivers be prolonged through it and the Gate seaward. Then he sketched the vision that would be presented if the whole region were sunk 500 feet below its present level. The Pacific would flood the Sacramento, San Joaquin and Tulare valleys. The hills of San Francisco would be submerged. The Golden Gate would be widened two or three miles with an occasional island rising here and there. The San José valley would be flooded and the waters connecting with those of the bay of Monterey would leave the Santa Cruz and San Francisco mountains as islands lying parallel to the Contra Costa and Diablo ranges. Los Angeles would go under, and the Gulf of California—Cortez's Vermillion Sea—would push 200 miles farther north But this, instead of being a fancy sketch, was probably a true picture of California as it existed *not long since*—speaking after the manner of geologists. That it was so is shown in many places, but nowhere so distinctly perhaps as at the upper end of the Tulare valley, where hills of horizontal strata are now strewn with the teeth of sharks, 10 or 12 different species, all of which are believed to be still living in the adjoining ocean. The first recognition of the existence of the mackerel family in the Pacific was by Agassiz, from their teeth, [which, we may add, the lecturer collected on these hills 8 years ago.] Since then, the fishermen have brought in living specimens,

The mountains settled, Prof. Blake next took his audience to the valleys, which he disposed in four groups —the low and broad valleys, whose extent make plains of them, the elevated mountain valleys, the plateaux of the Great Basin and the river valleys or canons. Among the first group is the great valley lying between the Sierra Nevada and the Coast range, its area over 16,000 square miles, more than the combined areas of Massachusetts, Rhode Island and Connecticut. We cannot stop to reproduce even "in little" the lecturer's graphic picture of this valley, in which so much of New England might be cradled without cramping; a valley that, except along the courses of the streams, and where its slope up the foot of the hills may be shaded with oaks, is treeless and even shrubless, its surface in the dry season parched and free from grass, its temperature by day rising often from 100 to 110 degrees, and the mirage constantly deluding the traveller along it. But his sketch of the Colorado Desert, which he included in his first group of valleys, we must not pass without remark. He pronounced it as fine a specimen of the desert as that of Lybia or Sahara. It extends from the base of San Bernardino southwesterly 180 miles, part of its surface being below our boundary line in Sonora. Its area is some 9,000 square miles; and excepting the Colorado, which cuts across its lower end, is without river or lake. It stretches off to the horizon on all sides without one glimpse of vegetation or life. Its surface is ashy and parched; its frame of mountains rise in rugged pinacles of brown rock, bare even of soil. Words are unequal to the task of describing its apparent expanses, the purity of its air, the silence of its night, the brilliancy of the stars that overhang it, the tints of the mountains at daybreak, the looming up of those beyond the horizon, the glare of the midday sun, the violence of its local storms of dust and sand. Parts are entirely destitute even of sand, being smooth, compact, sun-baked clay; other parts are covered with heaps of sand, disposed like snowdrifts in waves of 50 or 80 feet in hight. Near the mountains along the Colorado there is a terrace as flat as a floor and paved with pebbles of nearly uniform size, of porphyry, jasper, quartz, cornelian, and agate, all rounded by the action of water, and polished till they glisten, by the driving sand. In this respect, again, the porch of our Great Desert is like that which outlies the Lybian Desert. Doubtless the northern part of the desert is the dry bed of an ancient lake of fresh water, whose beach lines are strongly marked. Probably, at a comparatively recent period, the waters of the California Gulf covered all the clay surface of the desert. It lies below their level now, and if a channel were cut through the natural embankment of the Colorado, it would doubtless be covered again with water. It was very probable that the Colorado Desert region was uplifted within *historic* times. Earthquakes occasionally agitate its surface, and in 1852 there were eruptions of mud and hot water in the central parts of the valley.

Next were rehearsed the characteristics of the Great Basin, so named by Fremont, and of the newly discovered "Death's Valley," east of Owen's Lake, which by the barometrical readings lies at least 377 feet below the level of the sea—the bed of a dried-up lake covered with layers of salt from one to three feet in depth, while all the water about it is bitter and nauseating—an American Dead Sea, whereof the sea has died out literally."

Mons. Auguste Rémond in articles on the geological constitution of the Sierra Nevada, which recently appeared in the *Mining and Scientific Press*, writes as follows:

The Sierra Nevada, which to the East partly bound California, unite southward with the Coast Range; to the North, it is united with it by Lassen's Butte and Mount Shasta. The flank of those mountains presents a considerable development; the distance from the base to the ridge is more than sixty-five miles, and their highest points of elevation reach 15,500 feet above the level of the sea.

The western slope of that vast chain being from north to south, composed almost of the same rocks, I shall speak but of that section of country including the towns of Knight's Ferry, Sonora and Columbia.

The Sierra Nevadas can be considered as being principally composed of three distinct formations. They are, from bottom up, granites and sienites, cambrian schists, and saccharoid limestones. To these may be added the tertiary deposits, which skirt the foot of the chain, and the volcanic products scattered over a great part of its surface.

We shall not speak particularly of the relative age of those different formations, nor explain the revolutions they have undergone; this will be the subject of a special article.

The very base of the Sierra Nevada mountains commences at twenty miles from Stockton. From that point a gentle undulation of the surface is observable, and small hills of tertiary formation are seen on every side; horizontal strata cropping out in long lines on their sides. Hills of this character soon limit the view on each side; and, at first of slight elevation, they rise gradually, as far as Knight's Ferry, on the Stanislaus. At this point, the tertiary hills rise high above the stream, and the strata, which are distinctly exposed, lie piled together nearly 2000 feet thick. The strata of these formations are perfectly horizontal and composed of limestone, sandstones and thick beds of conglomerates. (R. R. Exploration.)

These tertiaries were deposited immediately after the principal upheaval of the Sierra Nevadas, during the pliocene period; some are found resting on the schists or slates, and some on the granite.

These sedimentary deposits have ramifications, which spread as far as Montezuma, Scraperville, Whimtown, Dentville, etc....In some other places of California, the sandstones are variously dipped, but we must attribute that to different volcanic phenomenon which were effected during the quaternary epoch and the recent traces of which are found everywhere.

That singular formation, known under the name of Table Mountain, belongs to the same period. This mountain is formed of an immense overflow of basalts, which seem to come from the east. The volcanic matter, when fluid, outspread and produced a series of table lands or broad steps, each of them being several miles long, which are gradually losing their thickness, as far as Knight's Ferry, where they cover the tertiary strata in several places. These basaltic rocks are irregularly cut, and are seen near Montezuma, and not far from Abbey's Ferry. A beautiful view of them can be obtained from the Raw Hide Ranch. At some distance from Knight's Ferry, one enters the schistose formations, after having gone across one, the first flat summit of Table Mountain. There, the nature of the strata is entirely changed. The beds are not horizontal, but present a high angle of dip, having been upheaved to the east by the Sierra. At the first glance, their inclination is believed to be toward the west, because the schistose rocks can, in this respect, occasion many errors, from their being split in every direction. They present two inclinations—one apparent and the other true. Besides their division in beds, these schists are split almost perpendicularly, and it is this second divivion which deceives at the first sight; for, the first strata following the slope of the mountains, the second, which are perpendicular to them, will appear slightly dipped to the west.

There are only these last beds that are to be seen on the surface; sometimes they rise above the soil in masses twenty or thirty feet high, at others their height is such that the astonished traveler would take them for graveyard tombstones. The vertical position of the slates is one of those peculiar features which attract the attention of almost every person traveling in this country. From their appearance, resembling memorials in an old churchyard, they have been termed the gravestone slates. These rocks bear no characters, it is true, but they will always say much more than the best engraved inscriptions.

These schists extend from Knight's Ferry as far as Sonora; at or very near this hight they are no longer seen.

Those ancient sedimentary strata, which previously were but schistose clays, have been transformed into argillaceous schists or slates, in which are inserted beds of sandstones; near the point of contact with the granites and sienites, those formations have been powerfully modified by volcanic heat. These metamorphoses attract attention principally before reaching Sonora. Here are high hills of white talcose and micaceous schist, long veins of steatite with pure talc in them, are met with—elsewhere, the Cambrian sandstones have been turned into quartzites, which appear as though they had been violently struck forth from the inner to the outer sides. Two miles from Jamestown, on this side of the Table Mountain, there are two hills of a remarkably singular appearance; they were formed by the upheaval of a vein of quartzite or metamorphic quartz, which stretches from north to south; its length is more than twenty-eight miles, and it goes through Carson Hill, Campo Seco, Coulterville, etc. These veins are almost always auriferous.

All these rocks of the Cambrian epoch have more or less lost their first aspect. The greatest part of them contains sulphuret of iron, and in the schists of Table Mountain the pyrites are found in beautiful cubic crystals of a shining yellow. In these primary formations, veins of amianthus and carbonate of lime, with different other minerals, are also met with.

Strata of slates, perhaps Silurian, seem to lie in unconformable stratification over these different Cambrian deposits, as may be seen one mile from Montezuma, at the foot of Table Mountain. In some places, the schistose matters are divided in very thin pieces and form pretty good slates.

On going out from these primitive formations, the white limestones are entered; these extent like a long and narrow belt, wanting, or rather disappearing in different places, and in some others being two miles broad. These limestones, as the schists above described, are metamorphic rocks, for primitively they were the bottom of a deep and probably cretaceous sea. Those beds of chalk, when the sienites and granites were lifted up by the trap rocks, have been upheaved, overthrown and deeply modified; at that time they lost their first appearance for the crystalline structure they now posess, took various colors and were turned into those beautiful marbles which are found near Columbia, Sonora, and many other places, and so much admired.

There, the white limestones which underlie the vicinity of the first town, Columbia, and form the base upon which it is situated, are peculiarly compact and finely granular; they are seamed and veined with blue, and sometimes appear like a mixture of blue and white grains, forming a very good marble. The blue lines are generally parallel, and correspond to the trend of the beds. These layers of beds are evident marks of the sedimentary origin of these marbles. (R. R. Exploration.)

The surface of these rocks is very unequal, being furrowed by deep crevices, filled up with gravel and auriferous blue clays; when the earth is removed from the fissures, the limestone stands like irregular columns or big walls, having a slight inclination, and presenting the most whimsical forms. Sometimes the miners find large pieces of asbestos between the clay beds and the limestones, as in Sawmill Flat for instance.

The marbles of Tuolumne county can be divided into two principal kinds, each of them including several varieties. Some are coarse-grained and highly crystalline; their color is bluish, or white with blue lines. It is this kind that is the most common and which predominates in Sonora. The other saccharoid marbles of the second kind attract notice, with respect to the small blue lines which cross each other in every way, within a white paste; in certain varieties the colored seams disappear, and then the limestone possesses a bright whiteness; but in others the white color is entirely gone, and it has been replaced with a dark blue tint, inclining to black.

What distinguishes principally these species is the composition—the first being pure carbonate of lime and the second generally containing silica.

The schists and sandstones are found passing into these limestones, the limestone passing into the quartz, the quartz into granites, the granites into sienites, the sienites into feldspar, etc.... All things in creation are links of an immense chain, the rings of which are perfectly united, and that, as well among the rocks as among living beings.

On the other side of Abbey's Ferry, the metamorphic limestones rise to the hight of 1,000 to 1,800 feet above the level of the Stanislaus river: they lie upon the granites and form irregular layers more than 600 feet thick. Some of them are in a state of decomposition.

It is in this kind of rock are met those caves and caverns filled with such pretty stalactites, and which attracted so much attention from their containing Indian bones, discovered some years ago. From time to time, in the county of Calaveras, I found on the slopes of those marble mountains, masses of lime entirely crystallized and sometimes slightly colored with green and yellow. Some of the specimens I secured, when analyzed by Dr. Snell, proved to be both lime and baryta.

One may say, without error, that the crystalline limestone extending like a long belt on the Sierra Nevada, forms the demarcation line between the schistose strata and the granite formations.

The granites and the sienites, which much resemble them, appear at Sonora. Beyond this town, Bald Mountain, from the summit of which the Mount Diablo range is seen, is but a granite mass, traversed westward by veins of milky quartz; at its base extent mica-schists and some metamorphic gneiss. This last rock is also found on the side of a hill a quarter of a mile from Sonora; specimens of it are now in the scientific cabinet of this town.

Sometimes the sienites, which cover large surfaces on the Sierra Nevada, are exclusively made of grains of orthoclase (glassy felspar,) scattered through a greenish and a little crystalline base of amphibole. Actinolite is found in long and slight green crystals in the cavities of these rocks. At other times, the orthoclase forms the principal compound of the sienities, and hornblende is met with in flat and elongated crystals. The felspar often disappears, and in this case the rock passes into amphibolite, as may be seen near Abbey's Ferry.

As for the granites, they are much different from each other, and every locality, if I may so speak, has its own.

The most common are a compound of quartz and felspar. filled with small spangles of black mica. Very often the surface of them is decomposed and in a crumbling state, forming hills of a peculiar rounded form, or surmounted by piles of stones which are sometimes like heaps of boulders. On the southern banks of the Stanislaus, these igneous rocks are stratified and in almost horizontal layers, being but slightly lifted up to the north. This is a proof that the primitive matter became cool very slowly. In certain places the granites are covered with rocks entirely felspathic. They also undergo a change, but their decomposition is not so perfect as to be used for *kaolin*. It is very easy to see that the granites of the Sierra Nevada chain are of two different ages. The older are generally greyish in color and contain much *quartz*; in the newer, *orthoclase* predominates, and gives to the mass a white color spotted with shining black mica, as is observed near Soulsbyville and on the sides of Bald Mountains. The sienites and granites often include large crystals of felspar; in this case the rock is porphyritic and passes into porphyry.

All these plutonic rocks are steeper as one goes on through the mountains, and form the main body of the Sierra Nevada. They are traversed by metalliferous quartz and glassy felspar (orthoclase) veins, which, from south to north, follow each other in almost parallel lines.

The first of these veins are the most common and the most important, because gold is generally found in them in larger or smaller quantities; they were formed much sooner than the quartzites or metamorphic quartz of the schists. The gold they contain is sometimes so fine as to be invisible to the naked eye; at others, the quartz when broken, is completely studded with the glittering particles. If gold is found in quartz veins it does not prove that it was originally formed in that rock or together with it; for, says Sir Charles Lyell,* gold has now been detected in almost every kind of rock, in slate, quartzite, sandstone, limestone, granite and serpentine, both in veins and in the rocks themselves at short distances from the veins. The presence of this precious metal in the alluvial deposits is to be attributed to the gradual degradation of the gold-bearing rocks by water and atmospheric influences, which distributed the gold over this country. In every part of this mining region the quartz veins are seen cropping out. They are very irregular in their mode of formation; sometimes they rise up like enormous walls more than 60 feet high, then suddenly sink down into the bowels of the earth to incalculable depths. Those crystals of quartz (or pure silica) which so well decorate collections, are found in the cavities or pockets of these rocks. The quartz very often contains pyrites and sulphuret of lead which crystallizes in steel gray cubs. Here, it is to be remarked that galena always contains silver, as sulphuret of iron contains gold, but both are in so small a quantity that it is too expensive to take them out.

The veins of glassy felspar attract notice in the vicinity of Kincaid flat and Soulsbyville. Orthoclase, when pure, is white, and presents pearly reflexis which are very agreeable; but generally it is colored and tarnished by other substances. These felspars, in some localities, are filled with plates of white mica, crystals of garnet and of tourmaline. The sward silicates are in small red twelve-sided crystals; this stone is a little similar to the rubies found throughout the Sierra Nevada in the sand and gravel of river beds, and which are very fine, bu generally very small. The third silicates are always crystallized and of a beautiful shining black. Sometimes the crystals are capillary, at others they are very large. I measured some of them which were two inches in diameter and six inches long. All the rocks are fine specimens for mineralogical cabinets.

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*Elements of Geology, last edition, p. 300.

The metalliferous deposits scattered within these crystalline rocks contain almost all the most important metals; gold, silver, platina, manganese, are found in them; magnetic iron or loadstone is common, and the carbonate of iron (sideros) is also met with. Near Coulterville, cinnabar (sulphuret of mercury) is in small crystals of a small scarlet color; fine antimony, lead, copper, when sulphurets, form the minerals named blende, stilbite, galena, chalkosine, and are found in the Mariposa country. The two carbonates of copper, malachite and azurite, must take place with the above mentioned metals. Certain quartz which present fine green and blue tints are colored by those carbonates.

The volcanic rocks of the Sierra Nevada contribute to its formation; they are less ancient, but the most irregularly scattered. They have pierced through the different formations, and in some places covered them, as was the case at Table Mountain. With these igneous rocks, we must rank the vast plateaux of trapp which are found principally to the north on the Sierra Nevada chain, and all the volcanic cones, with lava and scoriæ. I shall notice but Lassen's Butte. Its summit is distinctly crateriform, and it is a volcanic cone whose fires have not long been extinguished; it has an altitude of about 9,000 feet and is covered with piles of lava and ashes. The craters of the coast range are probably of the sam age, having a similar character. In many places of the Sierra are seen traces of an intense and recent volcanic action; here and there the surface is covered with blocks of scroriaceous trapp, pumice, trachyte, porphyry or felspathic lava.

It is not very uncommon to find obsidian* in the vicinity of these volcanic rocks; this stone is probably the result of glassy felspar vitrified by the heat of those ante and postdiluvian volcanoes.

In several places along and beneath Table Mountain are thick beds of a gray aluminous clay, which forms a good kind of marl. These argillacious deposits occupy the bottom of a small flat between Shaw's flat and Whimtown. Strata of this character are not rare on the Sierra Nevada, and are the beds of ancient lakes.

Near Texas flat and Abbey's Ferry, the calcareous tufas are seen forming deposits, 70 or 90 feet thick. They assume every kind of arborescent and stalactical shape, and are perforated with caverns and grottoes of the most curious aspect; the carbonates of lime were formed before this epoch, and seem to have been lifted up and broken in many places; their position above the level of the Stanislaus River is to the hight of 1,900 feet. Westward, half a mile from Springfield, and on the side of Table Mountain, calcareous tufas of the same age are mixed with clay, and form what is called *calcareous marls.*

All the rocks and formations which I have just spoken of, are more or less covered with detritus and alluvial deposits, which increase every day and are divided from the degradation of the mountains by air, water or other physical causes. It is from the sands, gravels or clays of these alluvium that so many fortunes have been taken out.

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*Volcanic glass.

The same gentleman in his "notes on the upheavals of the Sierra Nevada," says,

It is difficult to ascertain with accuracy, the geological epoch during which the Sierra Nevada was upheaved, and therefore, the age of the mountains which go to make up the mass ot this Range. Nevertheless, from the geognostical position of the strata lifted up and contorted, we may say that the appearance of the Sierra Nevada took place during the tertiary period. This great event was thus conciding, in Northern America, with the upheaval of the Alps, in Europe.

The range of the Sierra Nevada was not upheaved all at once, but the volcanic action lasted during the following periods.

EOCENE, (TERRAIN PARISIEN).—The summits of the Sierra Nevada are like a long chain of islands stretching over the waters of a tertiary ocean; the quartz and felspar veins, the amphibolites, diorites and gneiss have long since been formed.

MIOCENE, (TERRAIN DE MOLASSE).—The Sierra Nevada rises out of the waters, and the cumbrian and cretaceous strata are violently lifted up. This overthrow, which was undoubtedly caused by the trapp rocks, resulted in the formation of the metamorphic limestones and schists, as well as the quartzites. A period of tranquility followed this cataclysm.

PLIOCENE, (TERRAIN SUBAPENNINE).—Slow upheaval of the Sierra Nevada still going on at the present epoch, as is the case in every part of California. This range of mountains is rising 6 feet in a hundred years (Humboldt); that is 3,000 feet during 50,000 years, which have passed away since the commencement of the pliocene epoch in California. Over the upheaval strata of the Sierra, are deposited the horizontal beds of the Knight's Ferry tertiaries.

In the diagram, which will be found at the commencement of this book, Mons. Rémond shows the geological constitution and relating position of the rocks, whether igneous or sedimentary, of which the great Sierra Nevada Range is composed.

[In the beginning of this work will be found an accurate diagram of a geological section of the Sierra Nevada, prepared by Mons. Remond. It clearly shows the relative positions of the rocks, whether igneous, sedimentary or otherwise, of which the great Sierra Nevada range is composed.]

THE MINES OF CALIFORNIA, OREGON, NEVADA TERRITORY, BRITISH COLUMBIA, ETC.

As this work is more particularly intended for those persons living in the above States and territories, it becomes necessary to give our attention for a short time to what are popularly termed "the mines of the Pacific coast." So much has been said and written on the subject of the discovery of the gold mines of California, that we consider it superfluous to burthen our compendium with more than a very brief review of the same.

It is stated on good authority, that the existence of gold in this State was known to the Jesuit missionaries many years ago—that M. Baric, a Frenchman, actually worked an auriferous quartz vein in 1843, near the mission of San Fernando, and that some British naval officers brought some fine specimens of gold-bearing quartz from this region nearly forty years ago. Hakluyt's account of Drake's voyage to this coast in 1579, states that at Drake's Bay, twenty miles north of the Golden Gate, gold or silver in reasonable quantities could be found in any of the earth—evidently a fabrication. In 1802, it was reported that silver was found in Monterey county, and in 1828, that gold had been discovered in San Diego county; but in 1835, Forbes wrote that no minerals of importance had been found in Alta California. Dana, who traveled through upper California with Wilkes' expedition, in 1842, speaks in his work of the existence of auriferous quartz in Southern Oregon, and in the Sacramento basin; remarking too, its resemblance to other gold districts. Thomas O. Larkin, U. S. Consul, at Monterey, in 1846 wrote to the then Secretary of State, that at San Fernando (Los Angeles) from one dollar to five dollars a day in gold could be made by washing certain black sand, which few have the patience to look for. He also stated that gold, silver, quicksilver, copper, lead, sulphur and coal mines were to be found all over California. On the 4th of Jan., 1848, James W. Marshall discovered a piece of gold at the lower end of a tailrace that had been dug at Sutter's mill, Coloma, El Dorado County. Sutter, Marshall and Humphrey then formed a mining copartnership. Marshall and Peter L. Wimmer, in the succeeding month, went to Mormon Island, and found gold there. Other parties, residing in different portions of California, hearing of the gold discoveries, visited Coloma, observed the "indications," noted the gold washing process, and returning home prospected their neighborhoods with success. Thus the extent of the gold-bearing region soon became apparent, and the newspapers teemed with accounts of wonderfully rich discoveries. Then from all parts of the world commenced an Hegira towards far-off California, such as had never been chronicled in the records of mankind, and ere long, thousands and thousands of hardy adventurers were busily plying the pick and shovel and extracting gold from a region of auriferous alluvium, some four hundred miles in length and one hundred in breadth. At the close of 1849, U. S. Commissioner, King, estimated that 55,000 miners were at work in the gold fields, that $40,000,000 had then been taken, and that in the succeeding year, 1850, the probable yield of gold would be $50,000,000.

Most people in the Eastern States and Europe imagined that Mr. King's estimates originated in a vivid imagination; but they were below, instead of above the mark! Hittel estimates the gold yield of this State as follows:

1848.	$10,000,000
1849.	40,000,000
1850.	50,000,000
1851.	55,000,000
1852.	60,000,000
1853.	65,000,000
1854.	60,000,000
1855.	55,000,000
1856.	55,000,000
1857.	55,000,000
1858.	50,000,000
1859.	50,000,000
1860.	45,000,000
Total	$650,000,000

Professor Whitney, our present State Geologist, in a work published in 1854, after carefully examining all the statements made by the California bankers and others, and the amounts deposited each year in the mints, divides the gold yield up to 1854 (exclusive), as follows:

1848.	$5,000,000
1849.	20,000,000
1850.	45,000,000
1851.	65,000,000
1852.	62,500,000
1853.	62,500,000
Total	$260,000,000

Although the two estimates differ very greatly when the yields for each year are compared, yet it will be observed that the two aggregate estimated yields for the six years do not differ so considerably, Whitney placing it at $260,000,000, and Hittel at $280,000,000; but as a vast amount of gold is taken away each year in private hands, of which no record is kept, it is impossible to estimate with any nicety. In reference to the future yield, Hittel thinks it will gradually decrease to $30,000,000 per annum, and remain at that figure for a long time; and the silver yield will gradually increase. There is no question in our mind that the latter assertion will prove correct, as extensive and valuable silver lodes have been discovered in various districts in this State and adjoining territories, large amounts of capital invested in their partial exploitation, and sufficient time has not elapsed for the fair development of these mines; but as regards the decrease in our gold yield we have some doubts, as that depends very materially upon the seasons —as may be seen at once, when we state that the winter of 1852–3 was the wettest ever experienced in California, and the most prolific in gold. As a rule, the drier the winter season the less gold is extracted, and *vice versa.* The excitements of late years, in regard to silver, copper and coal mining, have had a diminishing effect upon our gold product, as these new and valuable discoveries have diverted a very considerable number of our miners from gold searching, to prospecting for and working in silver, copper and coal mines. Other causes we might cite to prove that California, although she may be at present yielding less gold than formerly, is capable of yielding as much; and if our judgement is not mistaken, we shall see within the next year or two, a large increase. The unhappy civil war now agitating the Eastern States, and threatening to devastate them with all its train of horrors, will, without doubt, cause an unusual immigration by sea and land to the peaceful shores of the Pacific. Indeed it has already commenced. Many thousands of these new comers will naturally turn their attention to gold digging; thus the places of the silver, copper and coal prospectors and workers will be supplied, and our gold mines produce as much as in other years.

We now present to our readers a tabular chronological list of the various excitements that have agitated Californians since the great rush to this coast, commencing in December 1848:

Discovery of the Trinity Valley gold district, by Reading—Spring...1849
The Truckee Lake gold excitement *—June...............1849
Discovery of the Mariposa gold district by Fremont—Summer...1849

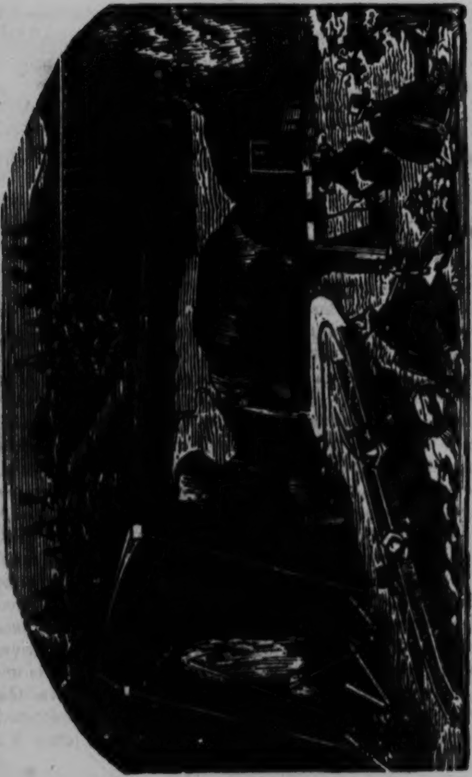
The Gold Lake excitement, *—May	1850
Discovery of the Klamath and Scott Valley gold districts	1850
The Gold Bluff excitement *—January	1851
The second Gold Lake (Sierra County) excitement *—Summer	1851
Discovery of the Australian gold fields	1851
The New Almaden quicksilver mines commenced yielding immensely	1851
Discovery of the Rogue River gold district, Oregon	1852
Discovery of the Carson Valley gold district	1852
Discovery of the Colville gold district, Was. Ter	1853
Discovery of the Yakima Valley gold district, Was. Ter	1854
The Amazon River (Peru) gold excitement *—Feb	1854
The Santa Anita, Russian River and mount Diablo gold excitements *	1854
The Kern River excitement *	1855
The Sacramento City gold excitemend *	1855
The Oakland gold excitement *	1856
Commencment of silver mining by American Companies in Arizona	1856
Discovery of Mono Lake, Walker's River and the San Gabriel gold districts	1857
Discovery of silver Districts in Nevada Territory	1857
Discovery of the gold districts of British Columbia	1858
Discovery of the silver and gold districts of Esmeralda (Mono County) and Coso (Tulare County)	1860
Discovery of the coal district of Monte Diablo, Contra Costa County	1860
Discovery of copper in Calaveras, Amador, San Joaquin, Stanislaus and Tuolumne counties	1861
Discovery of the Nez Perces gold region	1861
Discovery of rich cinnabar deposits in Napa, Sonoma and Solano counties	1861

* Those marked with an asteroid turned out to be humbugs.

Placer Mining, Etc.

In another portion of this work, we have spoken of mining, as carried on by tunneling and shafting. Placer and hydraulic mining will now briefly engage our attention. Herewith we present a wood-cut, showing the *modus operandi* of gold mining by tunnels, drifts and shafts, by the hydraulic method, and by the pick and shovel in shallow diggings. In the background of the sketch will be observed a water-flume, and near it a string of sluice-boxes, into which the miners are throwing auriferous dirt. To the left, some miners are tearing into the heart of the hill, with their water jets. Next to the right are others working with a "tom." Two more are engaged at the windlass, over a shaft which their hidden partners are sinking; and beyond them are two men shoving a loaded car along the tram-way, which leads from a tunnel in the hill—whilst in the foreground are others working the "rocker," and "panning out."

The first implement generally used in California for gold washing was the simple pan. This was followed by the Georgia "rocker," which is now used very seldom, unless by Chinese, with whom it is a favorite machine. It is very handy for prospecting, on account of its extreme portability. The next improvements were the short and long "tom"—a shallow box with a perforated sheet iron bottom, (shaped somewhat like the letter V,)



CALIFORNIA MINING SCENES.

through which the water, fine dirt and gold run into a sloping riffle-box beneath; the large stones being left upon said bottom, from whence they are shoveled away. The "tom" is of various lengths; from six to twelve feet as a general thing—and is in communication with sluice-boxes, into which the dirt is thrown by the miner, and thus swept down into the tom by running water. Nevada county, is, we believe, entitled to the honor of working the first "sluices"—which have since been adopted everywhere. The sluice-boxes are each made of three pine boards, with three cross-slats (one at each end and one in the centre,) of the open top. A series of these, resting upon posts or tresses, are fitted into one another, and are then called "a string of sluices." A slope or grade of three inches (more or less) is given to the boxes, and at the points where they fit into one another, they are "caulked" with old rags and tough clay, so as to prevent leakage. The tresses are placed under the head of every sluice-box, and thus also support the tail or end of the preceding box. Across the inside bottom of the boxes, near the head are tightly fitted slats about an inch deep. These are called "riffles" and here the gold is caught, some times with, and at others without the aid of quicksilver. There are an infinite variety of "riffles" used—but these are the simplest, and by no means the worst. As this is the most common mode of gold mining in this State, for persons without capital we will give a closer description of it, and matters connected therewith.

We will suppose that Peter, James and John are out on a prospecting trip. They have with them their picks, shovels, blankets and pan, besides their provisions, a frying pan and tin cups. They reach a creek, dig down for the bed-rock and reach it at a depth of seven feet. Filling the pan with dirt, one of them "pans out" a prospect, which if converted into coin, would be represented by three cents. At a distance of two feet from the bed-rock they try some more dirt, which gives one and a half or two cents, and from that up to the surface, they find prospects gradually dwindling down to a mere speck—commonly called "the color." They are in "luck," for these are good diggings. They "stake off" their claims—generally 100 feet in length to each man, and the whole width from bank to stream. Peter at once starts off to the nearest town, to purchase sluice-lumber, nails, a sluice fork, [illegible] axe, quicksilver, and more provisions. Meanwhile, James and John, dig a ditch to lead a "sluice head" of water from the creek to the head of their claims. Peter returns with the lumber, etc., and the ditch being finished (the water however not yet running in it,) they make the sluices and "set them," (on the ground if it slopes downward sufficiently) and, everything being in readiness, let on the water. Peter and James now commence on each side of the lower sluice-box to dig down to the bed-rock, throwing the dirt into the sluice. John is engaged in "stripping" or digging away the top dirt at some little distance ahead of his comrades, so that they will have a less depth of dirt to dig when they reach where he commenced. Now and then he looks down the sluices, and if they are getting choked so that the water is running over their sides, he seizes the fork and "forks out" the rocks; if he thinks there is too much or too little water running in the boxes, he takes his shovel and proceeding to the head of the ditch, regulates the supply as he may desire, now and then, too, he sprinkles quicksilver in the upper boxes. Thus they work until Saturday evening, when they leave off digging for the purpose of "washing down" and "cleaning up." John takes the fork, and proceeds to travel along the boxes from the lower to the upper ones, forking out the rocks, Peter and James assisting him by heaving out the largest with their hands. When the gravel and sand have been greatly reduced in quantity, James goes to the place where the ditch joins the creek, and at a signal from John, shuts off all but a couple of inches of water. Peter then takes a brush and scraper, with which he brushes and scrapes the amalgam and black sand down to the riffles in each box. The water is then entirely shut off, and the quicksilver, amalgam and sand is taken carefully out of each riffle and "dumped" into the pan. It is then "panned out" and the quicksilver squeezed through buckskin or stout drilling. The amalgam thus expressed is retorted or placed in an iron pan upon the fire until the quicksilver coating has evaporated, leaving nothing but the gold. If Peter James and John have worked hard during the week, they will probably feel pretty good about this time, when they see the golden result of their labor. The last operation is weighing the gold and dividing it—and whilst they are doing this, we will bid our quondam friends, adieu!

We have spoken more in detail concerning ravine or creek mining, because new comers almost invariably commence operations in this class of diggings, so as to "get their hand in," or until they have time to look around, and work or purchase into more extensive diggings knowingly. Besides the common sluice, above alluded to, there are the tail-sluice, the ground-sluice, and the rock-sluice. The tail-sluice is a string of boxes, much larger than the others, and similarly fitted to-where, being subject to a less violent motion, and passing through a greater variety of riffles, they are more likely to be finally arrested.

In diggings that contain clay, it is necessary to be very careful. The string of sluices must be very long, and not too steep, and their contents well worked with the fork and shovels. Often have we seen among the tailings of careless miners, round lumps of clay, which had come through the boxes, collecting and stealing the gold from the bottom as they rolled! Where the clay is very tough, it must be thrown into a "puddling box"—a large wooden trough with a hole, a few inches from the bottom—and soaked. Here it must be worked about and dissolved. The water is then drawn off, and auriferous sediment thrown into the sluices, or panned out.

The most extensive description of mining, is that by the hydraulic process—first applied by Mr. Matteson of Nevada. Whole mountains are torn into, and "razeed" by this process. It consists simply of a strong hose and pipe, leading water from a great elevation, and "squirting" it at the gravel and dirt, which are carried away through sluices. In claims, worked by the hydraulic process, blasting with gunpowder, has often been found a valuable auxiliary.

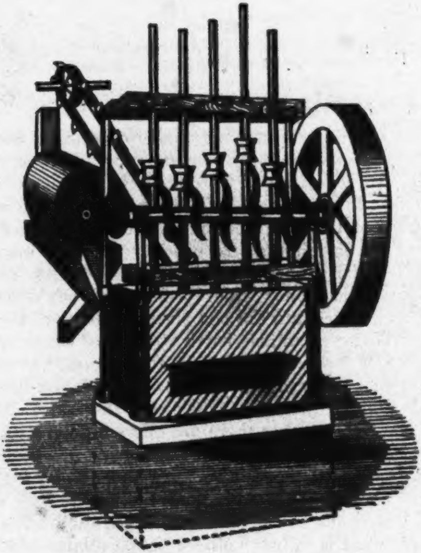
In river mining, the companies owning adjoining claims, generally club together and build a large flume, into which they turn the river by erecting a strong wing-dam of logs, rocks, leaves, mud, gunny-bags, etc. In this way the bed of the river is left comparatively dry, and can be worked. The sluices lead to the flume, and sometimes the water running in the flume is made to turn undershot wheels, connecting with machinery to pump the claims dry to the bed rock. Large boulders are met with in this class of diggings, and it becomes necessary in addition to the crowbars and other usual implements of mining, to have a derrick, with which to remove the heaviest rocks. Matteson's patent hydraulic derrick is the most convenient and valuable for this purpose; and we have therefore had an engraving of it made, (see frontispiece) the principle applied, being also capable of application to an infinite variety of purposes, for wherever water is cheap, the principle of hydraulic pressure, by Matteson's method, can be brought into play, impelling any fixed machinery, at far less cost and with less risk to property and life than steam or any other motive power. Although not entirely original with him, yet the patentee has introduced great improvements in his machine. We will briefly describe it, as applied to the derrick. The water is conveyed through hose into a tube, from which it is forced into the centre of a hollow S shaped casting, called "the wheel." The water rushes in opposite directions from this point, through the curved arms, which are open at the end. The discharges, as in the case of the fire-works known as Catherine wheels, cause the arms of the wheel to revolve with more or less velocity, at the option of the person in charge, who governs the same by opening or shutting the gates that are attached to the apertures. This "regulator" is, as will be seen in the engraving, very ingeniously, yet simply contrived, the gates being connected by rods with a lever. The wheel is on an axle bar at whose other extremity is a cog-wheel which fits, into another cog-wheel, and thus turns the revolving drum to which the hoisting rope is attached. The power of the wheels and its speed, can be governed in a variety of ways, independent of the regulator. The power is increased, but the speed diminished by lengthening the arms of the wheel, and *vice versa*. The power and speed are both increased by enlarging the apertures of the arms, and increasing the "head" of water; both are also increased by a larger amount of "fall," or in other words, by taking the water from a higher elevation. Water power can be applied by this method in less time, at less cost, and with more satisfactory results than by any other. Matteson's machine costs one quarter less than an overshot water wheel. It can easily be taken down and removed to places inaccessible to other machinery. it is so simple in its construction that any one can work it; and is not liable to get out of repair. If it does, the repairs cost but little and can be done rapidly. One of these derricks is now operating at Nevada city. It has a 6-feet wheel, with 1¼ in. escape holes, working under a 60 feet pressure, and using but four inches of running water, conveyed into a tank or reservoir, which is drawn from while the wheel is at work. This wheel is of 3-horse power, and can do as much as fifteen men turning the crank of an ordinary derrick. With such great advantages, no wonder that it is becoming a favorite in the mines, wherever it has been put into operation. But, as we before remarked, it is equally valuable for other purposes: for running air-fans in tunnels, circular saws, planing machines, quartz mills, and in fact almost any kind of machinery where the proper fall of water can be had, and in those towns and cities where water is laid on, it can readily be applied to printing presses. We have seen a miniature model, from which our drawing was made, which, when connected with the water-pipe faucet, raised a weight of fifty pounds! From this, some idea of its immense capacity may be formed. The inventor of the "hydraulic derrick" is the same gentleman so justly famous for his application of hydraulic power to mining operations.

Tunnel and shaft mining as well as blasting, being treated of elsewhere, we now turn our attention to

PROCESSES FOR THE REDUCTION OF GOLD.

GOLD.—After quarrying auriferous quartz, the reduction processes generally consist simply of pulverizing the rock, and separating it from the gold therein contained. The quartz is first carted from the mine to the platform in front of the mill, where it is broken into small pieces about the size of one's fist or less. Another man, if the mill be a large one, then shovels the broken rock into what is called the "feeder"—a sloping box down which the rock slides into the bed-plate and beneath the stampers. Water pipes lead small streams of water into these feeders, if "wet crushing" be the process, but not when the quartz is crushed dry. The dry process is getting quite popular in certain portions of the State. And here we may remark that there are many different styles and classes of quartz mills, from the four or five stampers up to thirty-six or more. To give the uninitiated reader some idea of these mills, and the method of working them, we have had the annexed illustration made. The first is what is called "Moore patent quartz mill."

It will be observed that the drawing represents a five stamp battery; the framing of which is constructed of wrought iron, strongly braced with diagonal rods, the whole resting on a cast iron mortar bed. The stamps weigh five hundred pounds each and crush through wrought iron grates fitted in the mortar bed, which has an opening at the bottom. The mill is principally designed for dry crushing, and for this purpose it is found to be admirably adapted. The ore is fed in the hopper, shown in front in the cut. It is crushed on the grates;

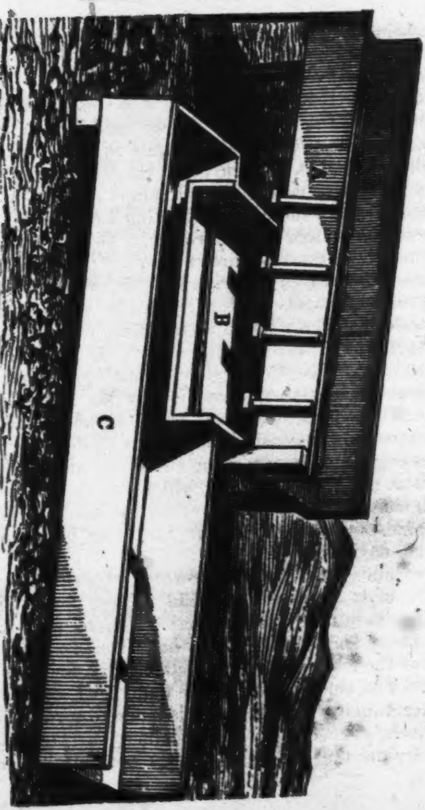


a large portion of it is at once reduced to fine powder, and passes through the spaces between the grates, into a channel cut through the mortar block, bending into an elevator which takes it all up, (coarse and fine) into a revolving wire screen, set on an incline. The portion of the ores reduced fine enough, pass through the screen into a funnel that discharges it ready to be operated upon by amalgamation; whatever portion is too coarse to go through the screen is discharged at the lower end of the bolt and returned to the battery by a conducting pipe to be crushed again. In this way ores may be crushed to any degree of fineness, by having the screens correspondingly fine. This battery can be constructed for wet crushing by substituting a solid mortar bed, with dies, instead of a perforated one with grates, and it can be made to discharge through screens on every side, if required. This mill recommends itself to those interested in mining, by its compactness and durability. It saves a large amount of labor and timber, by doing away with the cumbrous wood framing of the usual construction, and at the same time retaining the desirable features of simplicity, solidity, and other advantages of straight batteries; it is easily transported, and does perhaps more work than any other mill with the same weight of stamps. Several batteries of this construction are in operation in the Washoe silver mines, and it is pronounced by all competent judges to be one of the best mills yet introduced there. They are made exclusively at the Vulcan Iron Works, San Francisco.

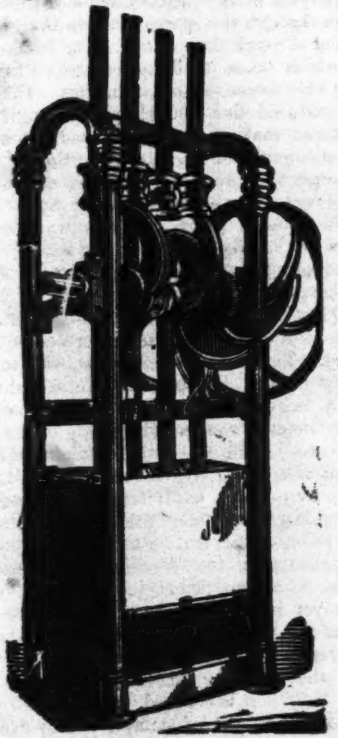
Another very excellent quartz mill, is the one represented in the following cut. It is known as "Bryan's Improved Mill." It is claimed, that this mill will crush, with the same weight of stamps, twenty-five per cent ally too, he washes a blanket over a wide shallow wooden pan or bowl, called a "battea," and panning out, ascertain pretty accurately how the rock in process of reduction will yield. In some mills the tailings after passing over the blankets and through amalgamating boxes, fall into a "Chili Mill,"—which consists of two iron wheels, running on one shaft, in the centre of which is a revolving pivot-shaft. In this manner the two wheels are made to run around a small basin, into which the auriferous tailings are washed, at the corner end of this basin is an aperture, through which the light tailings again escape, and are then conducted (in some mills) into an "arastra." The arastra consists of a revolving upright shaft to which two or four horizontal arms are attached. To each of these arms a large oblong piece of granite is appended by iron piles and chains, the front of these granite blocks being elevated about an inch from the bed whereon their rear ends rest, so that the tailings can be caught beneath each block and crushed as they are dragged around in the circular, which is paved with flat stones cemented together by tough clay. Quicksilver is occasionally sprinkled into the arastra as it works, so also in the Chili mill. The advantage of both these machines consists in the fact that they grind the quartzose matter to an almost impalpable powder and amalgamate at the same time. From the arastra the fine tailings are conveyed away through the last series of boxes, which are well supplied with "fancy" riffles, while at the end of the whole is some patent amalgamator. About once a week the battery, blanket boxes, amalgamators, Chili mill, arastra, etc., are cleaned up, and the sulphuret separated from the amalgam and quicksilver. The amalgam is then parted from the quicksilver by means of buckskin, the latter being squeezed away from the former. The amalgam is then retorted, and the gold is ready for sale or smelting.

In some places the quartz is reduced entirely by Chili mills and arastras, or either of them. This is because the proprietors of such ledges cannot afford, or have not sufficient confidence in their mines, to have more extensive works.

The methods of amalgamation are extremely diverse. In some mills quicksilver is poured into the battery, and two thirds of the gold is thus caught there. A copper plate coated with quicksilver and washed with nitric acid, is often used. Another amalgamating machine is a large copper bowl on an inclined plane, in which a heavy copper ball revolves, the copper being coated with quicksilver; another is a large shaking bowl, containing square compartments, into each of which in succession the auriferous matter is shaken; others are like Chili mills and arastras; another is a very long trough with a round bottom, along which are transverse groves, containing mercury. This is shaken like a cradle but slowly; another is a bowl containing a stirrer, somewhat in the style of an apothecary's pestle and mortar; another is formed of a series of amalgamating basins, one below the other, connected together by spouts. Through the centre of each basin runs revolving shafts to which are attached iron-shod mullers grooved. These run around and grind the pulverized rock upon perforated false bottoms, which can be taken out at convenience. Then there is one which comprises a series of compartments each below the other, the bottoms being covered with mercury, and so arranged that the tailings fall into one compartment, are forced under a partition, come up and fall into another, gether. A few large rocks are placed on the bottom at intervals from one another, so as to catch the sand and gravel that comes from the sluice boxes. About once a month they are "cleaned up." The rock-sluice is used for hydraulic mining. It is completely covered at the bottom with stones, so as to imitate the bottom of a stream, and requires to be of large size, and to have a steep grade—about one inch to each foot with a large head of water. The cobble-stone pavement on the bottom of these sluices, is held down by slats. Care must be taken to make the stones overlap one another, down-stream-wards. It is considered by parties, who have long used these sluices, that they save far more gold, than any others. The ground-sluice is cut into the bed-rock, whether that be hard rock, soft rock, or tough clay, and into this is thrown (or washed) the dirt above it. This is seldom used, except where the diggings are poor, or very shallow. The "under-current-sluice" is also coming into use in some parts of the State. Mr. Dunning, who invented and introduced it at North San Juan, speaks of it thus: By means of two or more iron bars at the termination of a section of sluice-boxes, forming a right-angle grating, a portion of the dissolved earth, fine gravel and water is separated from the lumps of hard earth, cobbel-stones and gravel, and drops into a set of more gently graded sluice-boxes beneath, when they flow slowly off in another direction, while the body of the water and coarse material dashes down a "dump" or "fall," to be again taken up in sluices with the tailings from the under-current, and subjected anew to separation. This process insures a more thorough amalgamation and saving of the particles of gold, the most of which drop through the grating into the under-current



DUNNING'S UNDER-CURRENT SLUICE.



BRYAN'S PATENT QUARTZ MILL.

more rock, than any other mill yet invented, and that it is also cheaper, more durable, and requires less power to work it. This mill too can be put up and be in working order in ten hours after its arrival upon the ground. Several mills of this patent are now working in Nevada Territory and this State.

The stampers of quartz mills are methodically raised by "cams" or arms, attached to a revolving iron bar called the shaft, which is turned by water or steam power. As each stamper reaches a certain height, the cam revolves from beneath it, so that it falls with all its weight upon the quartz on the iron plate. The stampers being heavily shod with iron, and weighing many hundreds of pounds, crush the quartz very fine. In wet-crushing the fine quartz, gold and water, are by the action of the stampers splashed violently against fine wire sieves, through which the matter when pulverized sufficiently, passes. When the matter is discharged from these screens, it falls into a sloping box, in which is placed a dash-board. from whence it flows down a series of inclined boards (like sluice boxes, only much smaller and with more "fall") which are covered with blankets in, the wool of which the richest tailings deposit. At the junction of each series of "blanket-boxes" are variously contrived amalgamation boxes, so arranged that the descending tailings are forced through the body of quicksilver therein contained. At the head of the inclined boxes a stream of clear water (sometimes *warm*, to assist amalgamation,) runs into each box, to assist the tailings in their descent. In well-regulated mills a man known as the "amalgamator" takes up the blankets, one after the other, and washes them in a large trough or box, containing water, replacing them with others; occasion-

and so on. There is another amalgamator which is like a chest of drawers, the bottom of each being perforated with half inch holes, those of the upper drawer being immediately over the unperforated portion of the lower—thus *ad infinitum.* But there are such multitudinous varieties of the amalgamator, that it would take up too much space to describe them.

In some descriptions of quartz the gold is almost entirely included in the sulphurets. The quartz in such cases is first crushed, and then by means of machines called "separators," the quartzose matter is separated from the pyrites. In the Pacific Metallurgical Works in San Francisco—perhaps the most extensive on the Pacific coast—the ore after being crushed by stampers, is further pulverized in Chili mills as in Fig. 1 by the dry process. The powdered ore is then conveyed up-stairs to the room shown in Fig. 2, where it is passed through a series of arastras—after which it is taken out and placed in vats. The quartoze, or other rock, in these vats being frequently stirred, much of the amalgam having a greater specific gravity, falls to the bottom, and is collected after the superincumbent mass of pulverized ore has been removed. The poorer crushed rock is then sent down-stairs again to room No. 1, where it is run through ingeniously constructed sluices and riffle boxes, where the residue of the gold (if that be the metal contained in the ore) is amalgamated. The amalgam is then passed into an adjoining room, Fig 3, which is the Assaying Department. This room is full of furnaces of various kinds, crucibles, cupels, acids, and all the other concomitants of a well appointed Metallurgical Laboratory. Here the amalgam is strained and retorted, the metal then being smelted, refined and run into bars. The large furnace seen to the

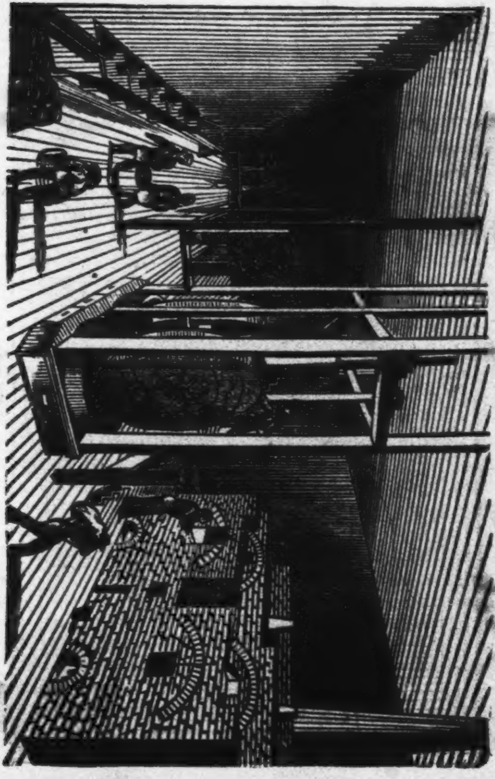


FIG. 1.

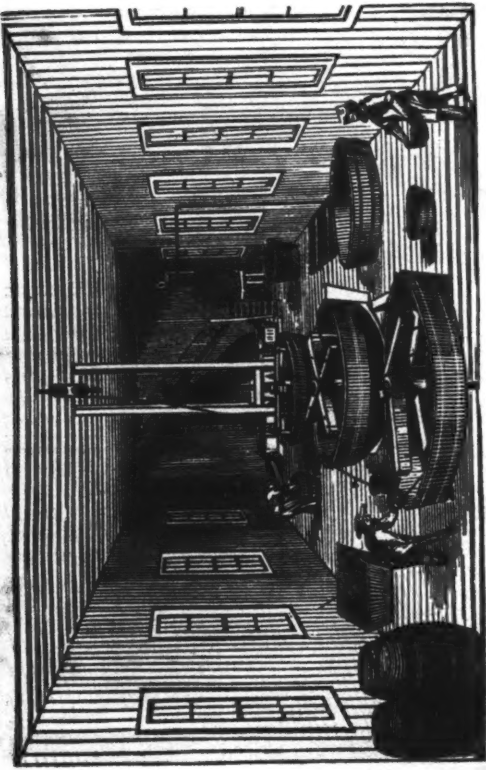


FIG. 2.

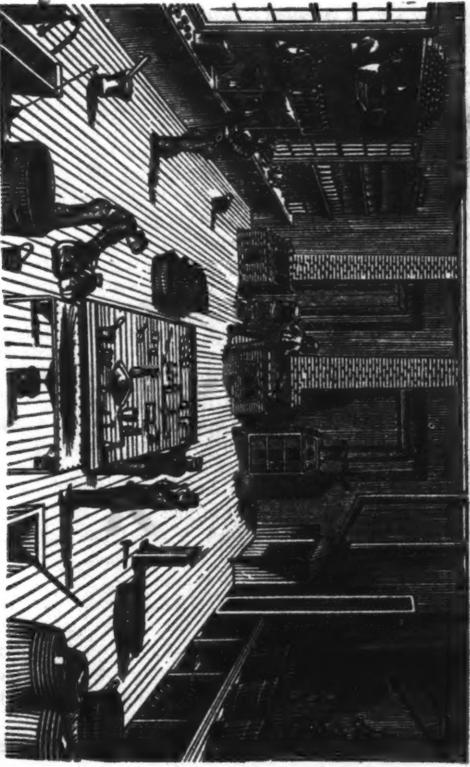


FIG. 3

right of Fig. 1, is called a reverberatory furnace, and in this the sulphurets, after separation, are retorted.

These works are conducted on the European plan. Both wet and dry processes are used, and the works are capable of reducing three tons of ore per day, going through all the various manipulations of parting, assaying, smelting and refining. Thus the metal contained in twenty tons of ore—whatever it may be—can be returned in fine ingots to the owner in one week. Ore has been reduced here from the Dana Lead, the Gould & Curry, Lucerne, Bailey and other mines in California and Nevada Territory, besides ores from Mexico, Arizona, and other portions of Western North America. In testing ores it is advisable to send to the works at least one ton, so that a fair approximation of its general richness may be arrived at. When necessary, these Metallurgical Works can reduce double the quantity of ore above spoken of, by doubling the power, which they can do without the addition of new machinery. With works so complete as these, it is downright folly to send ore to Europe for reduction. Nothing more can be done there than here—and by shipping it to Europe the additional cost of transportation, cost of insurance, and great loss of time are incurred. Ore that will not pay to send to Europe, will furnish a profit if reduced here.

SILVER. Processes for the reduction of silver ore vary greatly. First there is the Mexican process. Mr. Ward in his work on "Mexico," gives the following interesting description of this process, as practiced with the ores of the Valenciana mine at the Hacienda of Salgado:

The ore, on being extracted from the mine, is placed in the hands of *Pepenadores*, men and women, who break the larger pieces with hammers, and, after rejecting thoin which no metallic particles are contained, divide the rest into three classes, called, in mining language, *Azogues*, and *Apolvillados Buenos*, or *Ordinarios*. The *Azogues* are the inferior ores, in which the matrix contains but a thin sprinkling of silver. As this increases, it becomes *Apolvillado ordinario*, and *Apolvillado bueno* when very rich. Sulphuret of silver, where it occurs but little intermixed with other substances, is designated as *Polvillos*; (probably because when reduced to *polvo*, dust, this dust is found to be richly impregnated with silver;) and *Molonques*, or *Petanques*, are the names given to the masses or crystallizations of pure silver, which are not unfrequently met with. The three last are too rich to be submitted to the ordinary process of amalgamation; but the *Azogues* and *Apolvillados* are transmitted in *costales*, (miner's sack,) weighing 150 lbs. each, to the Hacienda, where they are delivered to the Administrador, (overseer,) who gives a receipt for the amount. They are then submitted to the action of the morteros, (stamps,) one of which of eight stampers, (mazos,) is capable of reducing to powder ten cargas of ore, (each of 350 lbs.,) in twenty-four hours. This powder not being thought sufficiently fine for the quicksilver to act upon it with proper effect, it is transferred from the morteros to the arrastres, (crushing-mills,) in which water is used. Each of these reduces to a fine, impalpable, metalliferous mud, six quintals of powder in twenty-four hours. At Guanajuata, where water-power cannot be obtained, the arrastres are worked by mules, which are kept constantly in motion at a slow pace, and are changed every six hours. The grinding-stones as well as the sides and bottom of the mill itself, are composed of granite, four blocks of which revolve in each arrastra, attached to crossbars of wood. This part of the operation is thought of great importance, for it is upon the perfection of the *Molienda*, (literally, the grinding,) that the loss of quicksilver is supposed in a great measure to depend. It is performed usually in a covered shed, or *Galera*, which, in a large hacienda like Salgado, from the number of arrastres at work at the same time, is necessarily of considerable extent. From the arrastres the ore is again removed to the *Patio*, (amalgamation court,) where it is disposed in *Tortas*, the size of which varies according to the dimensions of the patio, or the fancy of the Administrador, (overseer.) The number of Montones, (heaps,) contained in each Torta, is consequently uncertain; but the monton of Guanajuata consists of nine cargas, and two arrobas, or thirty-two quintals of ore; each carga containing fourteen arrobas of twenty-five pounds.

The monton requires three arrobas of salt, (from Colima,) at one dollar, or nine reals, the arroba. This is added to the mass three days before any other ingredient.

One arroba of ordinary magistral, (from Tepesalar, near Aguas Calientes,) or seven pounds of the very best quality, (Pepena.)

Quicksilver, in the proportion of three pounds for every marc of silver that the ores of the monton are supposed the amalgamator to contain, and varying, consequently, according to the quality of the monton, which is determined by the eye.

In the amalgamation of a large Torta, the same proportions are always observed; and the mass is repeatedly worked up by men and mules, (repasadores,) in order to promote the incorporation of the silver with the mercury, which it requires six weeks in winter, and one month in summer, to effect. When the amalgamator supposes the Torta to have *rendido*, i. e., to have yielded all the silver that it contains, it is washed in large vats, (Tinas,) until the earthly particles are got rid of, when the amalgam, which remains at the bottom of the vat, is strained in leather bags until no more quicksilver can be separated from the silver by pressure. The remainder is cut into wedges, which are conveyed to the Quemadero, (burning-house,) and arranged in a circular pile round a copper plate called the Vaso, with a hole in the center, and a receptacle for water beneath, care being taken to make the hollow left in the center of the pile of amalgam correspond exactly with the hole in the Vaso below. The whole is then covered by a large iron bell, called Capella, or Capellina, which is strongly luted down; a wall of mud bricks is raised round it, and the intervening space filled with charcoal. The fire is kept up for twelve hours, in which time the quicksilver is sublimed, and afterwards condensed in the water, where it is subsequently collected. The pure silver (Plata quemada) is then cut again into wedges, or melted down into bars, (containing 135 marcs each,) in either of which shapes it may be transmitted to the mints.

The loss of quicksilver at Salgado in the whole process, in the year 1825, amounted to nine ounces on each marc of silver; but this was thought to be an instance of very successful management, on the part of Mr. Belauzaran, as the proportion is, in other Haciendas, from ten to eleven ounces. He attributed the difference to the excellence of the *Molienda*, which he always caused to be continued until there was nothing harsh, or gritty, in the mass upon which the mercury was to act. He added, that the residue of the Torta, when washed, might contain some small portion of silver, but it had not been found that the quantity was sufficient to repay the cost of any farther process, and it was consequently thrown away.

The best of the *montones* which I saw at Salgado, were expected to produce fourteen marcs of silver; and those of an inferior quality, eight marcs. Two marcs and a half pay the costs of reduction, which amount to twenty dollars on the monton. Allowing as much more for raising the ore, and the share in the general expenses, there would remain a profit of three marcs, or twenty-five and a half dollars, on each monton of the poor *Azogue* ores; while on the richer *montones* it would amount to seventy-six and a half dollars, including the loss of quicksilver, which, in 1826, was worth six reals per pound.

In other portions of Mexico, the process varies somewhat from the above, but the difference is not material.

Another is what is called "the European process." This is admirably described by Phillips, in his Manual of Metallurgy, from which we extract:

The amalgamation of silver ores is perhaps more systematically and economically conducted at Halsbruecke, in the vicinity of Freiberg, than in any other European locality. The usual constituents of the ores there treated are sulphur, antimony, arsenic, silver, copper, lead, iron, and zinc, which are more or less mixed with various earthy minerals, besides sometimes containing small quantities of bismuth, gold, nickel, and cobalt. In the selection of these ores, they are so assorted as not to contain above 7 per cent. of lead, or 1 per cent. of copper, as from combining with the mercury added, these metals give the amalgam a pasty consistency, and thereby render the treatment extremely difficult and expensive. The mixture of the different ores obtained from the mines is so arranged that the charges of the furnaces shall contain seventy-five to eighty ounces of silver to the ton of mineral; it is also essential that they should contain a certain proportion of sulphur. This usually exists in the form of iron pyrites, which, on being roasted, gives rise to the formation of the sulphate and oxyd of iron necessary to the success of the subsequent operations. If, as is sometimes the case, the amount of pyrites naturrally occurring in the ores is not sufficient for these purposes, addition is made either of this mineral, or in some instances of ready-formed sulphate of iron.

The ore, when thus prepared, is laid on a large floor, forty feet in length and about twelve in width, and on the top of it is thrown about 10 per cent. of common salt, which is let drop from an upper room, through a spout placed in the floor for that purpose. The heap, when it has been thus made up of alternate strata of ore and common salt, is well mixed by being carefully turned over, and is subsequently divided into small parcels called *roast posts*, each weighing from 3½ to 4½ cwts. The salt annually employed for this purpose at the Halsbruecke works amounts to three hundred tons, and is supplied by the Prussian salt mines.

The mixture of ore and salt is now roasted in reverberatory furnaces provided with fume flues for the reception of any pulverulent matters which may be mechanically taken over by the draught. The prepared charge is spread on the bottom of the hearth, where it is at first very gently heated, for the purpose of expelling the the moisture, which to a greater or less extent it invariably contains. During the process of drying, which usually occupies two hours, the charge is kept constantly stirred by a long iron rake, and when this operation is considered sufficiently advanced, the heat is so far increased as to cause the ignition of the sulphur, and to render the ore red-hot.

The furnace is kept at this temperature for about four hours, during which time the metals become oxydized, and sulphurous acid gas is rapidly given off, whilst the ore is by constant stirring prevented from becoming agglutinated in masses. The temperature is now still further raised, and sulphurous acid is again given off, together with vapors of chloride of iron and hydrochloric acid. The hydrochloric acid generated at this stage of the operation is due to decomposition of the chloride of iron, by the action of oxygen and watery vapor. This last firing, which occupies about three quarters of an hour, is continued with constant stirring until a sample taken from the furnace ceases to envolve any odor of sulphurous acid, and has for its object the decomposition of the sea-salt by the metallic sulphates produced. During this process the ore increases considerably in volume, and assumes a deep brown color. When the roasting is terminated the charge is raked from the furnace on to the floor of the establishment, from whence, after having been allowed to cool, it is removed for the purpose of being passed through a set of fine sieves, by which the finer powder is separated from the agglutinated lumps. These are broken down to a proper size, and after being mixed with a fresh quantity of sea-salt are again roasted in the usual way. The finer particles are on the contrary, taken to a pair of heavy mill-stones where they are reduced to the state of an impalpable powder. At the Halsbruecke works there are fourteen roasting furnaces, and as many pair of granite millstones, which, together, are capable of preparing and grinding about seventy tons of ore per week. The ore, after passing through the mill, which makes from one hundred to one hundred and twenty revolutions per minute. is sifted through a dressing aparatus, which renders it as impalpable as the finest flour.

The reactions produced by the process of roasting are the following :—The sulphurets of iron and copper give off sulphurous acid gas, and are transformed into oxyds and sulphates. The sulphuret of silver, on being heated in contact with the sulphates of iron and copper, is converted into sulphate, whilst these metals become oxydized, and sulphurous acid is evolved. The sulphates of iron and copper, together with the salt with which they are mixed, become fused even below a red-heat, and if sulphuret of silver be present in the mixture, a further amount of sulphurous acid is evolved, through the decomposition of that mineral, produced by the reaction of its sulphur on the sulphuric acid of the sulphates; whilst sulphate of soda, chloride of silver, and the chlorides of copper and iron, are formed at the same time. When these reactions are conducted with free access of air, the iron becomes partially converted into susquioxyd, whilst a corresponding amount of the susquichloride of that metal is produced. The sulphurets of antimony and arsenic are likewise at the same time oxydized, and we may therefore regard the roasted ore as being composed of sulphate of soda, chloride of sodium, chlorides of manganese and lead, susquichloride of iron and subchloride of copper, chloride of silver, sundry earthy impurities, and various metallic oxyds.

The amalgamation of this prepared ore is performed in twenty wooden casks, arranged in four rows, and each turning on cast iron axles, secured to the ends by means of bolts. These barrels, which are two feet ten inches in length, and two feet eight inches in internal diameter, are made of oak staves three and a half inches in thickness, and are further strengthened by iron hoops and blinders. On one of the ends of each tun is placed a toothed wheel, which works into another toothed wheel, mounted on an axle, which receives its motion directly from a water-wheel. Above each of the tuns so arranged is placed a wooden case, into which is thrown the prepared mineral, and which is furnished with a leathern hose, for the purpose of introducing the powdered ore into the different barrels. With this view, each cask is furnished with a circular opening, and an iron or wooden pin, which is employed for running off at the termination of the process, the argentiferous amalgam.

The basins, situated immediately above each tun, are of such a size as to exactly contain the amount of water necessary for one charge. Below the tuns, and a little above the surface of the ground, are placed triangular troughs, destined to receive the various elaborated products at the termination of the operation. At the commencement of the operation, 3 cwts. of water are run into each barrel from the reservoir, after which 10 cwts. of the finely ground and sifted ore are introduced through the hose. To this are added from 78 to 100 lbs. of wrought iron, cut into fragments of about an inch square, and three-eighths of an inch in thickness, and which, in proportion as they become dissolved by the action of the substances by which they are associated, are replaced by fresh pieces. The casks are now tightly closed by screw stoppers, and as soon as they have all been charged, the apparatus is thrown into a gear by the means of a screw, and the sliding block, which cause the tuns to rotate with a rapidity of from eighteen to twenty turns per minute. At the expiration of two hours the machinery is again stopped, and the tuns are opened for the purpose of examining the state of the metalliferous paste which they contain. If the charge is too firm a little water is added, but if, on the contrary, it is found to be too liquid, a small quantity of powdered ore is thrown in. When this has been attended to, 5 cwts. of mercury are poured into each cask, and the tuns, after being securely closed, are again thrown into gear, and kept constantly revolving for sixteen or eighteen hours, at the rate of from twenty to twenty-five turns per minute. During this time they are, however, twice examined, for the purpose of seeing whether the paste which they contain be of the proper consistence, for if it be too thick the partilces of mercury are not sufficiently brought into contact with the silver contained in the ore, and if too much water has been added, they remain at the bottom of the cask, and are not sufficiently mixed with the different constituents of the charge. In the first case it is necessary to add a small quantity of water, and, in the second, a little powdered ore. After the introduction of the mercury, the temperature of the casks becomes considerably raised by the chemical changes constantly going on within, so that, even in winter, it sometimes stands as high as one hundred and four degrees Fahr.

At the expiration of twenty hours the amalgamation of the silver is ordinarily complete, and the tuns are now entirely filled with water, and again made to turn two hours, with a velocity of only eight revolutions per minute. The amalgam is by this means separated from the slimy matters with which it was mixed, and collects in one mass at the bottom of the tuns. When this aggregation of the amalgam has been accomplished, the different casks are successively thrown out of gear, and are stopped with their apertures immediately over the spouts. A small peg in the bung is now removed, and the liquid amalgam flows out and is received in the triangular spout; the workman closely watches this period of the operation, and the moment any of the earthy matters begin to flow from the orifice, it is again tightly closed. The mercury is now run off through the iron tube, into the gutter, by which it is conducted into a receiver prepared for that purpose.

The casks are now turned with the apertures upwards, and as soon as the bungs have been removed, they are again brought back to their former position, and the muddy residuum is discharged into a spout, from which it flows into large reservoirs situated at a lower level. This residuary ore is found to be stripped of its silver to within about five and a half ounces to the ton, and is therefore often subjected to another amalgamation. The emptying and discharging of the casks occupies about two hours, and the whole process is therefore finished in something less than twenty-four hours. In fourteen days one hundred and sixty tons of mineral are treated in this establishment, every five tons of which require an expenditure of fifteen pounds of metallic iron, and two pounds twelve and three quarters ounces of mercury; so that every pound of metallic silver produced is obtained at an expense of 0·95 of an ounce of mercury.

During the first two hours that the casks are set in action, and before the introduction of the mercury, the susquichloride of iron contained in the ore is decomposed by the metallic iron present, and converted into protochloride. If, instead of operating in the way described, the mercury were immediately introduced into the casks, it would, by reacting on the perchloride of iron, become partially converted into calomel, which, not becoming again reduced during the subsequent stages of the operation, would be productive of a considerable loss of this valuable metal. This inconvenience is, however, completely avoided by the action of the metallic iron, as the protochloride thus formed is entirely without action on metallic mercury. The chloride of silver contained in the roasted ore is held in solution with the chloride of sodium, and becoming reduced to the metallic state by the constant agitation with the metallic iron, combines with the mercury to form a liquid amalgam. The chlorides of lead and copper are decomposed at the same time as the chlorides of silver, and enter into the composition of the amalgam produced.

When the residual earthy matters are drawn off from the casks, the pieces of metallic iron are retained by means of grating, whilst the slimes, after being run into proper receivers, are conducted into *pug-tubs*, where they are constantly kept stirred with a large quantity of water.

These tubs are furnished with openings at various distances from the bottom, by which the muddy water is successively drawn off, whilst a certain quantity of amalgam is found collected at the bottom of the vessel. This is collected at the close of the operation. and added to that obtained by tapping directly from the amalgamation-tubs, as before described.

The mercury and amalgam obtained from the casks is afterwards filtered through close canvas bags, by which the liquid quicksilver is separated from the pasty amalgam, which is retained by the closeness of the web, whilst the mercury passes through into reservoirs prepared for that purpose. The pasty amalgam which is retained in the bags consists of a mixture of six parts of mercury and one part of an alloy composed of about eighty per cent. of silver, and twenty of a mixture of copper, lead, bismuth, antimony, gold, nickel, zinc, and some other metals. This mixture is subsequently heated in a distillatory furnace, and is thus freed from the adhering mercury, whilst the nonvolatile constituents of the alloy are obtained in the solid form.

At Halsbruecke, the sublimation of the mercury is performed in furnaces, beneath which are placed wooden drawers, sliding in grooves, and supporting an open basin of cast iron; these themselves support a wrought iron stand, resting on four iron feet placed within them. This upright shaft passes through the center of five cup-shaped iron plates, which are placed at distances of about five inches apart, and are destined to hold the amalgam which is to be operated on. Over this is lowered, by means of a crane and chain, a cast-iron bell-shaped dome, supported by a wrought-iron framing, and furnished with a loop. A sheet-iron door is also employed for the purpose of closing up the front of the aperture when the amalgam has been placed on the support, and the bell has been accurately deposited over it. The total weight of the balls of amalgam placed in each furnace usually amounts to about 3 cwts., and after the bell has been let down over it, and the door closed, the basin is filled with water, and a fire, made with chips of firewood, is lighted on the plate, which has a hole in its center, and accurately fits the sides of the bell in the part where it is situated. Before closing the door, it is thickly lined with fire-clay, and the apertures existing between it and the wall are afterwards securely luted up.

When the wood has become well ignited, the space is gradually filled up with fuel, which consists at first of turf, and afterwards of charcoal. In this way the bell becomes red-hot, and the mercury, which is sublimed, falls down, and is collected in the basin which is constantly supplied with cold water, through pipes laid on for that purpose. At the end of eight hours, the operation is usually finished, and when no more globules of mercury are heard to drop into the water, the fire is allowed to go gradually out. When all is sufficiently cooled, the bell is removed by means of a crane, and the impure silver is taken from the shelves of the support. The mercury collected in the basin is, after being drained and dried, sent back to the works to be again employed in amalgamation, whilst the impure silver is refined by fusion, and subsequent cupellation. From each charge of amalgam distilled under the bell, about one hundred marcs (50 lbs.) of dish silver is obtained: this impure silver contains on an average twenty per cent. of other metals.

The dust obtained from the fume flues is from time to time removed, and, after having been ground with the crucibles which have been employed in the process of refining, are passed to the amalgamation-mill. The earthy residuum discharged from the amalgamation casks, on being subjected to a second treatment, yields about four and a half ounces of this crude silver to the ton, which, after being mixed with that obtained from the first process, is refined in the ordinary way. The supernatent liquor, run off from the tanks in which the *schlich* is allowed to settle, chiefly consists of solution of sulphate of soda, common salt, and sulphate of iron, together with small quantities of various other soluble salts. The earthy deposits from the second amalgamation still contain silver, but in too small amount to enable it to be profitably extracted.

Within the last twenty years, three new processes for the extraction of silver from ores, have been discovered and put into operation in Germany. Dr. R. H. Lamborn, who minutely described these processes in three letters to the Mining Magazine in the early part of 1861, and which descriptions may be found in Blake's "Silver ores and Silver mines," introduces the subject in the following extract, which for brevity's sake we are forced to confine ourselves to :

In point of priority of date, the plan of Huettenmeister Augustin stands first. It was invented about the year 1845, and brought gradually into use at Gottesbelohnung Furnace, near Eisleben, in Prussia. It has given place to the plan next to be mentioned, but is now used in Saxony and in Hungary. The distinguishing peculiarity of this plan is to be found in the fact that the silver is converted by a chlorizing roasting into chloride [AgCl.] and then dissolved away from its impurities by means of a hot concentrated solution of common salt. This plan may hence be appropriately called "Silver extraction with salt water."

The second method, which was also invented in the vicinity of Eisleben, by Huettenmeister Ziervogel, another officer of the Mansfeld Mining and Smelting Company, consists essentially in converting the silver into a sulphate or vitriol, [$AgO.\ SO_3$] by means of a very careful roasting of the sulphides of silver, copper and iron in a draught of air, and then dissolving out this soluble salt with hot water. From the nature of the solvent, this plan may be known a "Silver extraction with warm water." It is now in use at the Gottesbelohnung furnace, and at Swansea in Wales.

The third and most recently invented method is that of Von Patera, "Metallurgic Chemist for all Austria." It is in use at Joachimsthal, and has, as far as I am aware, never yet been described with any degree of minuteness. It consists essentially in a transformation of the silver of the ores into a chloride, by roasting with common salt, and a subsequent dissolving out of the same with a solution of the Hyposulphite of soda, [$NaO.S_2O_2$] and percipitating the silver from this solution as a sulphide, by means of five-fold sulphide of sodium [$Na\ S_5$.] The process may hence be denominated "Silver extraction with Hyposulphite of soda."

As we before remarked, our limited space forbids more extended details of the first and second methods, which are used, the former (Augustin's) at Freiberg, and the latter (Ziervogel's) at Mansfeld. A review of the difficulties in the application, and of the causes of loss of metals in each of the two methods, translated from the French of M. L. E. Rivot, will in conclusion be given:

In Augustin's method, the essential point is the production of the chloride in the dry way. When the whole of the silver is changed to chloride, and the greater portion of all the other metals is left in the state of oxyds, the operation is a successful one, and there is no fear of losing any considerable portion of silver in the following operations. The chloride is easily soluble in a warm liquid containing 22 per cent. of salt, and the lixiviation and precipitation only require care on the part of the workmen, and the attention of an intelligent superintendent.

The difficulties of chloridizing in the dry way, are very great, not only in the operation itself, but principally in the preceding operations of roasting and calcining. In changing all the silver present into sulphate by calcination, at a low temperature in the presence of an excess of air, sulphates of all the other metals are formed. These may be almost completely decomposed by a prolonged calcination, but it is not possible to raise the temperature high enough to attain the desired result wtthout decomposing the sulphate of silver. The sulphates of iron and copper may be almost wholly decomposed ; but those of lead, zinc, cobalt, and nickel, remain almost unchanged. The success of the *calcination* thus depends, in part, upon the care taken by the workmen, but chiefly upon the chemical composition of the matt submitted to treatment.

The transformation of the sulphates into chlorides should be rapidly made, at a low temperature, as the chloride of silver and the chlorides of the other metals are volatile. The chlorides of iron and of zinc are the most volatile, and produce the greater part of the loss in silver. By carefully conducting the roasting and calcination, the quantity of chloride of iron may be much diminished, but it is not so with the chloride of zinc. It is therefore essential to avoid submitting matts containing zinc to the process. Only a portion of the volatilized chlorides is collected in the condensing-chambers above.

With matts containing arsenic and antimony, the difficulties are much greater. Roasting at a low temperature with an excess of air, changes nearly all the arsenic and antimony into arseniates and antimoniates which cannot be decomposed by calcination, and must be changed into chlorides. A longer continued and greater heat is required in chloridizing; and the formation of a large quantity of chloride of iron cannot be avoided. The loss of silver by volatilization of the chlorides, is much greater than with the pure matts.

In Ziervogel's method, applied to very pure matts, the chief difficulty is to so modify the temperature during calcination, as not to destroy the solubility of the sulphate of silver in water. For this part of the elaboration of the matts, the method is much superior to Augustin's, since it avoids the difficulties and the causes of loss in chloridizing.

The solution of the sulphate of silver in water is always very slow and difficult, and it cannot be known when it is complete. It is necessary to assay the residues for silver, and to roast over again those that are too rich. This richness of the residues in silver entails a loss which is nearly equivalent to the loss by volatilization of the chlorides in Augustin's method. There cannot be a great difference between the proportion of silver taken from the matts by the two methods, and it can only be presumed, if the operations by each are conducted with all the necessary precautions, that the loss of silver is a little the least by Ziervogel's. The expenses, also, being less, this method is, without doubt, the most advantageous for very pure matts.

When the matts contain a notable proportion of arsenic and antimony, there is always a certain quantity of arseniate and antimoniate of silver formed, which are insoluble in water, even when recourse is had to mixing lignite with the charges, or to the action of steam thrown in upon the sole of the furnace, as at Freiberg.

All the silver so combined is necessarily lost; while in Augustin's method, a portion of the chloride of silver formed from the decomposition of the arseniate and antimoniate during roasting, may be expected to remain in that state during the process of lixiviation.

It cannot, therefore, be said that with matts containing arsenic and antimony, Ziervogel's method yields more silver than Augustin's.

Sufficient comparative experiments upon this subject have not yet been made, and from those that have, it cannot yet be decided which of the two methods is the most advantageous for extracting the silver from the impure matts. It is only well demonstrated that the loss in silver is, in all cases, greatly increased by the presence of arsenic and antimony.

The cupriferous residues are nearly equally charged with arsenic and antimony, but those left by Ziervogel's process contain basic sulphates which are very useful in smelting for black copper. By Augustin's method, there is always a notable loss of copper, and the residues are without sulphur.

GLOSSARY.

ACICULAR. In the shape of a needle.
Acute. Sharp at the end.
Adamantine. Resembling the diamond.
Alluvial. Relating to Alluvium. See *Introduction.*
Amorphous. Devoid of regular form.
Amygdaloid. A trap rock which is porous and spongy, with rounded cavities.
Arseniate. A salt, formed by arsenic acid, combined with any base.
Aqueous. Watery, formed by water.
Arsenic Sulphides. Sulphides containing arsenic.
Alkaline. Having the properties of alkali.
Argillaceous. Partaking of the nature of clay; clayey.
Abrasion. The act of wearing or rubbing off.
Azoic. Destitute of any vestige of organic life.

BARYTES. Heavy spar; Sulphate of baryta.
Bituminous. Containing bitumen or mineral pitch.
Black flux. Tartar deflagrated with half its weight of nitre.
Blowpipe. An instrument by which a current of air is blown through flame, directed upon any substance to fuse it.
Bicuspid. A point, pointed.
Boulders. Large rounded masses of rock, worn smooth by the action of water.

Botryoidal. Resembling a bunch of grapes.

Borax. A salt, formed by a combination of boracid acid with soda, used as a flux.

Basalt. A rock, of igneous origin, consisting of argite and feldspar, with grains of magnetic or titanic iron, and also bottle-green particles of olivine, frequently disseminated,—usually of a greenish black, dull brown, or black.

CAPILLARY. Hair-like; long and slender.

Clay-slate. A mineral found in the primary and secondary rocks. Colors, reddish, bluish, or greenish brown. Occurs massive. Structure, slaty. Lustre, glimmering. Yields to the knife.

Cohesion. The act or power of sticking together.

Cleavage. Capability of being divided in fixed directions.

Cube. A figure having six equal sides.

Cupel. A small cup, made of bone-ashes, and having a small depression on its upper surface, into which the substance is placed.

Conchoidal. Having bent elevations or depressions, in form like the shell of a fish.

Concretion. A small mass; a lump; a clot.

Carboniferous. Containing coal. *C. Limestone.*—A gray, compact limestone, found in secondary rocks, traversed by veins of spar. Often full of organic remains. Also called *Mountain or metalliferous* limestone.

Chlorite. A soft, green, scaly mineral, slightly soapy. It occurs in primary rocks.

Calcined. Reduced to powder by heat.

Conical. Round, and shaped like a sugar-loaf.

Conglomerate. Rocks composed of rounded masses, pebbles, and gravel cemented together. Often called *Pudding-stone.*

Cupriferous. Containing copper.

Cupellation. The refining of gold, silver, and some other metals, in a cupel, or by scorification.

Cobalt. A metal, of a reddish-gray, or grayish-white color, very brittle, of a fine, close grain, compact, but easily reducible to powder.

Crucible. An earthen melting pot, capable of enduring extreme heat, without melting; used for melting ores.

Crystallized. Formed into crystals.

Conformable. When the planes of one set of strata are generally parallel to those of another set, lying in contact.

Clinkstone. A mineral which has a slaty structure, and is generally divisible into tabular masses, usually thick, sometimes thin, like those of argillite.

Coniferæ. An order of plants, bearing cones, which contain the seeds.

DISSEMINATED. Scattered; occurring in portions less in size than a hazel-nut.

Deposite. That which is laid or thrown down.

Debris. Masses of rock, etc., detached from the summit and sides of a mountain, and piled up below.

Dentritic. Appearing like a tree.

Dodecahedron. A figure of 12 equal sides.

Ductile. That may be drawn out into wires.

Dentiform. Like a tooth in form.

Decrepitate. To crackle like salt when roasted.

Deflagration. Rapid burning attended with flame and vapor.

Drift. Earth and rocks which have been drifted by water, and deposited over a country while submerged. The surface is often scooped out into deep basin-shaped depressions and elevations. Scattered through it are large rounded rocks called *bowlders.* Platinum, gold, and diamonds are explored almost exclusively in this formation. It lies under *alluvium* and over *secondary* rocks.

Disintegrated. Separated into integrant parts without chemical action.

Denudation. The laying bare of rocks, by the action of running water, removing earth, etc., from above; strata exposed.

Detritus. A mass of substances, worn from solid bodies by attrition, and reduced to small portions.

Diluvium. A deposit of superficial loam, sand, gravel, pebbles, etc., caused by the deluge or ancient current of water.

EFFERVESCENCE. Boiling; bubbling.

Erosion. The act of eating away; corrosion.

Erupted. Forcibly thrown up by igneous action.

FUSIBLE. That may be melted. To *fuse* is to melt.

Fibres. Threads. *Fibrous.*—Presenting fine threads o slender lines.

Foliated. Consisting of plates or thin layers.

Fissure. A Cleft. a chasm; an opening running lengt wise.

Fracture. The manner in which a mineral breaks.

Fluor, Fluor Spar. A mineral much used for orname tal vessels; found mostly in metallic veins in prima rocks.

Flux. A substance used to promote the melting of metals.

Fossils. Organic substances, which have become penetrated by earthy or metallic particles, and are found in rocks or the earth; petrified forms occurring in strata.

Ferruginous. Partaking of iron; of the color of the rust or oxide of iron.

Friable. Easily pulverized or reduced to powder.

GLANCE. A dark colored metallic sulphuret.

Globular. Round; like a ball.

Geognostic. Pertaining to a knowledge of the structure of the earth. *G. Situation.*—Position or locality in the earth.

Gneiss. A stratified primary rock, of a striped aspect. It is rich in metallic ores.

Granular. Consisting of grains.

Granite. An unstratified primary rock. Colors, gray, grayish white, and flesh red. It is the lowest rock.

Graywacke. A grit-rock or sandstone, composed of rounded pebbles and sand united together. Occurs in secondary rocks.

HEXAHEDRAL. Having six equal sides.

Hornstone. An impure variety of flint. Color, grayish or yellowish white. Found in primary mountains.

Hackly. Having short, fine, and sharp points on the surface.

Hornblende. A mineral of a dark-green or black color. Hornblende slate occurs in primary rocks.

Homogeneous. Of the same kind, similar parts, or a like nature.

INCRUSTING. Covering with a crust.
Igneous. Proceeding from the action of fire.
Interstratified. Stratified among or between other bodies.
Indurated. Hardened; made obdurate.
Infusible. Not fusible.
Infusion. Steeping in water or liquor.
Inclination. Leaning; deviation from an upright position.
Iridiscent. Like a rainbow.
Intumescence. A swelling, enlarging.
Iron pyrites. A mineral of a yellow color; lustre brilliant. Hard and brittle. Appropriately denominated *fool's gold.*
Investing. Covering, coating.

LAVA. A mass of melted minerals and rocky matter, ejected from volcanoes. The same when cold.
Lacustrine. Pertaining to lakes or swamps.
Loam. A soft, easily soluble, natural mixture of sand and clay, with oxyd of iron.
Lithological. Pertaining to the character of a rock, as derived from the nature and mode of aggregation of the mineral contents.
Limestone. Stone of which lime is made by the expulsion of its carbonic acid, or fixed air. It is called carbonate of lime.
Litharge, A semi-vitreous oxyd of lead, produced in refining silver by cupellation with lead. It appears in the form of soft flakes, or semi-transparent, shining plates.
Levigate. To rub or grind to a fine powder.
Lamina, -næ. A thin scale; a layer or coat.
Lamelliform. Having the form of a plate or scale.

Lias. A kind of limestone, occurring in flat, horizontal strata. Found in secondary rocks.

Lamellated. Composed of, or covered with, thin plates.

Lute. A composition of clay or other matter, used for stopping the joining or seam of vessels, so as to be air-tight.

MAGNETIC. Possessing the properties of the lodestone; attractive; having the power of drawing or lifting iron-filings.

Mica-slate. A stratified rock, one of the most common of the primary class. Generally it is capable of being split. It is extensively used for flagging the side-walks of cities.

uffle. An open-shaped vessel, made of earthenware, flat below and arched above, open at one end and shut at the other, and at the sides, except where it is perforated with small holes.

alleable. That may be drawn out and enlarged by beating.

embranous. Consisting of thin parts formed by fibres interwoven like net-work, serving as covers.

arl. An earth or clay, usually in fine powder, confined to the alluvial and tertiary strata. Effervescence on the application of an acid. Often used as a manure.

assive. In mass; of irregular form.

atrix. The place or substance in which metals are formed or produced; gangue.

ispickel. Arsenical pyrites; an ore of arsenic containing this metal in combination with iron, generally irregular, but sometimes occuring in cubic crystals.

iocene. The middle division of the tertiary strata, containing fewer fossil shells of recent species, than the *pliocene*, but more than the *eocene*.

Mica. A mineral, generally occurring in shining particles, capable of being split into very thin plates. Its colors are various; it is often by ignorant persons, mistaken for gold.

NEUTRALIZE. To combine substances in such proportions that the compound will not exhibit the properties of either.

Nodular. Presenting irregular globular elevations.

New Red Sandstone. The group of rocks immediately above the coal measures or strata. Its usual color is brick-red. Often occurs colored in stripes and spots. It contains occasional beds of gypsum and rock-salt.

Nest. A collected mass of any ore or mineral in a rock.

OBLONG. Longer than broad.

Outcrop. The coming out of a rock to the surface of the ground.

Oxide. A combination of oxygen with another body; rust.

Oxygen. The vital part of the atmosphere.

Octohedron. A solid having eight equal sides.

Opaque. Not transparent.

PRISM. A solid whose ends are any equal plane figure, and whose sides are oblong.

Pulverulent. Dusty; consisting of powder.

Pyramid. A solid whose sides have one common point or top.

Primary, or Primitive Rocks, The group of rocks lowest in order. They consist of clay-slate, quartz rocks, hornblende-slate, talcose-slate, serpentine, limestone, mica-slate, gneiss, and granite. They are irregularly crystallized, collected without a cement, and contain no animal relics. They lie below the secondary strata.

Porphyry. An unstratified rock, in which are imbedded crystals. It is either red, purple, or green. Found in the primary.

Plumose. Resembling feathers.

Plateau. A plain or flat surface.

Pseudomorphous. Not having the true form.

Pyrites. A combination of sulphur with iron, copper, cobalt or nickel, presenting a white or yellowish metallic lustre.

Parting. An operation by which gold and silver are separated from each other.

Precipitate. To throw a substance in solution to the bottom of the vessel containing; the substance thrown down.

Palæozoic. The lowest fossiliferous strata, the earliest forms of life.

Pachyderm. An order of mammals, which have hoofs, but do not ruminate.

QUARTZ. Pure flint, occurring in glassy crystals. Rock-crystal is a variety. Abounds in all rocks.

Quartzose. Containing quartz; partaking of the nature of quartz.

REDUCED. Separated from foreign substances.

Reniform. Kidney-shaped.

Right Angle. A corner formed when a perpendicular line falls on a horizontal one.

Reciprocating.	Backward and forward, or up and down.
Rhomboidal.	Having the shape of a four-sided figure, whose sides are equal but corners unequal.
Reverberatory.	A furnace with a kind of dome that drives back the flame upon a vessel placed within it so as to surround it.
Ramose.	Full of branches.
Reticulated.	Resembling net-work.
Regulus.	The pure metal.
Ridges.	Long elevations of land.
Ranges.	A line of mountains.
Retort.	A spherical vessel of iron, with a long hollow bent neck.
SCHISTOSE.	Slaty.
Sulphate of Barytes.	Heavy spar, a mineral.
Stratified.	Arranged in layers.
Shaft.	A long narrow opening into a mine.
Secondary Rocks.	Those situated above the primary and below the tertiary. They are mostly made up of sand, clay, and pebbles cemented together, and contain a great many organic remains. They consist chiefly of chalk, green-sand, clay, limestone, marl, red sandstone, sandstone, coal, carboniferous limestone, &c.
Serpentine.	A mineral found in primary limestone, gneiss, and mica-slate. Colors, green, yellow, brown and gray. Receives a high polish. Soapy to the touch. Yields to the knife.
Schist.	A slaty rock.
Specific gravity.	Weight compared with water.
Streak.	Color a mineral presents when scratched.

Scoria. Dross; rejected matter; scum; slag.

Spangle. Anything sparkling and brilliant.

Shale. A fine grained slaty rock.

Stalactical. Resembling an icicle.

Sectile. Being cut with a knife, the separated particles do not fly off but remain.

Splendent. Shining, glossy.

Spar. Any cystallized earthy mineral, splendent.

Sublimation. Changing a solid into a state of vapor by heat, and then bringing it again to a solid by cold.

Silurian. The fossiliferous strata below the old red sandstone.

Sedimentary Deposits. Deposits of materials, from a state of suspension in water,

Superimposed. Laying or imposed upon some other strata.

Sandstone. A composition, consisting chiefly of quartzose matter, united by a cement, calcareous, marly, argillaceous, or even silicious; either close or loose in texure, with granular or earthy fracture.

Specular Iron. An ore of iron, occurring frequently in brilliant metallic crystals; the peroxyd of iron.

Striated. Marked with fine parallel lines; long, narrow, separable parts laid on or beside each other.

Spatula. A slice; an instrument used for spreading things.

Soluble. Capable of solution; susceptible of being dissolved in a fluid.

Slag. See *scoria.*

Stratigraphically. Arranged with military precision in layers.

Scorification. The operation of reducing a body, either wholly or in part into scoria, or slag.

Sulphuret. A combination of sulphur with a base.

Sulphide or *sulphite.* A salt, formed by a combination of sulphurous acid with a base.

TALCOSE-SLATE. A primary rock, soapy to the touch.

Tessular. Related to the cube.

Tenacious. Sticky, adhesive.

Translucent. Clear; letting light pass through.

Tabular. Having the form of plates or laminae.

Tertiary Rocks. Those lying above the secondary and below drift, consisting of sandstones, clay beds, limestones, green-sand, gypsum, rock-salt, lignite, &c., with animal relics.

Transition Rocks. The lowest uncrystalline stratified rocks.

Trap. An unstratified rock among the primary, of a greenish-black or grayish color, and often arranged like stairs.

Triturate. To rub or grind to a fine powder.

Tuberous. Knobbed.

Trachytic. Pertaining to trachyte, a nearly compact, feldsphatic, volcanic rock, breaking with a rough surface, and often containing crystals of glassy feldspar, with sometimes hornblende and mica.

Tetrahedron. A solid figure comprehended under four equilateral and equal triangles.

Trend. To run, stretch, tend, incline or bend in any direction.

VITREOUS. Glassy.

Volatile. Apt to go off in vapor.

WACKE. A soft variety of trap, resembling the toad, and of a greenish-gray, brown or black color.

Zinc-blende. An ore zinc, called also "mock-lead," "false galena," and "black jack." It generally contains more than half its weight of zinc, about one fourth sulphur, and usually a small portion of iron. It is a sulphuret of zinc.

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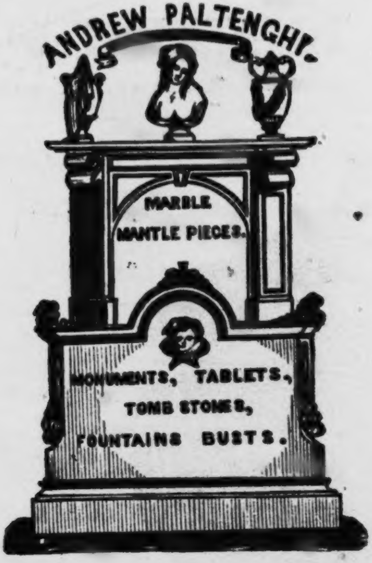
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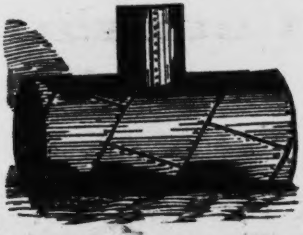

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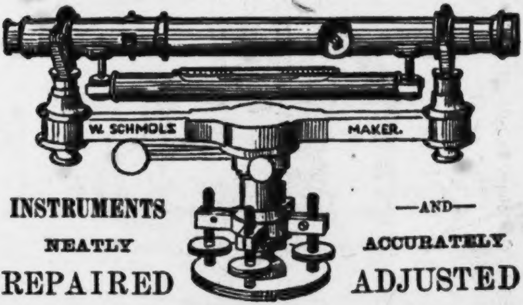

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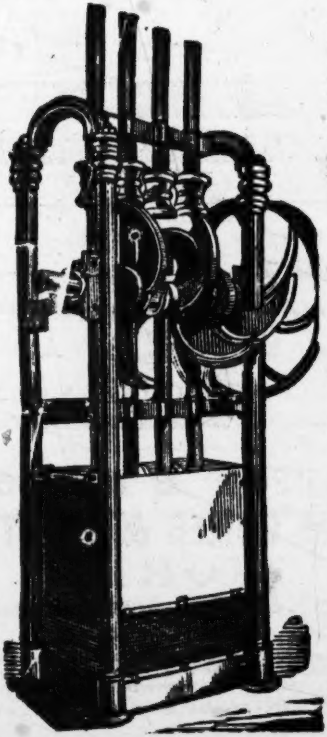

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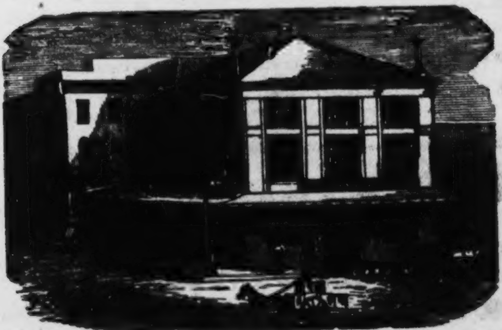

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